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OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

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THE DETERMINATION OF ORBITS

BY L. B. STEWART

THE determination of the orbit of a heavenly body, especially in the case of a comet, affords one of the most fascinating problems in the whole range of astronomy. As a consequence we find that the attention of a great many astronomers and mathematicians has been attracted to it, so that the literature of astronomy contains many descriptions of methods that have been devised for effecting its solution. It is proposed in this article to give a general account of the problem, without going much into mathematical details, and to show the result of some observations of Halley's comet taken by the writer in May and June last.

In the first place, the determination of an orbit and the position of the body in its orbit at some assumed epoch, involves the determination of six quantities, termed the elements of the orbit. These are :

Ω, the longitude of the ascending node, and
i, the inclination of the plane of the orbit to that of the ecliptic,

which determine the position of the orbit plane ;

a, the semi-axis major, or mean distance, and
e, the eccentricity,

which determine the form and dimensions of the orbit, if elliptical ;

ω, the angle between the ascending node and perihelion,

which determines the position of the orbit in its plane ; and finally

M, the mean anomaly at some assumed epoch.

In the case of a comet a and M are usually replaced by

q, the perihelion distances, and
T, the time of perihelion passage.

That six quantities are necessary for determining the motion of a body which is acted upon by a force directed to a fixed centre, whose intensity varies inversely as the square of the distance of the body from that centre, appears from the fact that the differential equations of motion are three in number and of the second order, so that their integration will lead to six arbitrary constants, which when known will completely determine the motion. The solution of these equations furnishes a proof of Kepler's laws of planetary motion, extending the first to include all conic sections, and showing that the third is an approximation, though in the case of the bodies of the solar sytsem a very close approximation. The constants of integration may be expressed in terms of the elements of the orbit as above defined.

Newton was the first to attack the problem of determining the orbit of a heavenly body from a limited number of observations, and in the *Principia* he lays the foundation of Theoretical Astronomy — including under that head the portions of the science which relate to the determination of orbits — as well as that of celestial mechanics. He there gives a graphical method of determining the orbit of a comet, which is assumed to move in a parabola, from three observed positions, and he acknowledges that the problem is one of considerable difficulty. His method, though graphical, is susceptible of numerical computation, and this plan was followed by Halley in applying Newton's method to cometary orbits. Newton also exhibits the application of his method to the comet of 1680, and endeavors to identify it with two which appeared in the years 1106 and 531 A.D., thus having

a period of about 575 years. Chambers, however, states in his "Handbook of Astronomy" that its orbit as afterwards computed by Encke from the observations has a period of 8814 years, and that the observations might also be satisfied by an elliptic orbit having a period of 805 years, or even by a hyperbolic orbit.

All the great mathematicians from Newton onward have contributed to the solution of the problems of celestial mechanics, and the invention of the infinitesimal calculus placed a powerful instrument in the hands of these investigators for unlocking the secrets of the universe. Indeed the methods developed by Newton have remained where he left them, and no mathematician since his time has attempted or been able to reach further discoveries by following in his steps; what was required was a new method of research, and that was supplied by the calculus.

The celebrated mathematicians Lagrange and Laplace led the way in developing and applying this method, and both published solutions of the problem of determining parabolic elements of a cometary orbit, but as stated by Watson in the preface to his work on "Theoretical Astronomy," "the solution given by the former while analytically complete, is far from being practically so; and that given by the latter, though especially simple and practical as regards the labor of computation, leads to results that are so affected by the unavoidable errors of observation that they are often little more than rough approximations."

The most successful method from a practical standpoint was that published by Olbers in 1797, and it is still the basis of all the methods used at the present time in determining parabolic elements from three observed positions. It is founded upon the principle, approximately correct, that if $a\ c$ be the chord joining the extreme positions of a comet in its orbit, and $A\ C$ the corresponding chord of the earth's orbit, the radii-vectores at the middle position cut $a\ c$ and $A\ C$ proportionally to the times occupied in describing the arcs. This assumption is but little in error if the intervals between the observations are nearly equal, and the arcs described small. It also made use of a theorem of parabolic motion due to Euler, and afterwards extended by Lambert to

apply to the ellipse and hyperbola, and which will be again referred to below.

Olbers' method has received a good deal of attention from later mathematicians who have modified and extended it so as to render it applicable to certain exceptional cases in which the other methods failed.

By thus assuming the parabolic form for an orbit, one of the elements, the eccentricity, is supposed to be known and equal to unity, thus greatly simplifying the solution of the problem. The general problem of determining all the elements, including the eccentricity, is much more complex, and remained unsolved until the discovery of Ceres by Piazzi directed the attention of Gauss to this problem. A brief account of this discovery and its result may not be out of place.

On January 1st, 1801, Piazzi while searching for a star catalogued by Wollaston, but which could not be found in the position he assigned to it, observed a faint star, which by January 3rd had changed its position. He wrote at once to Oriani, and to Bode at Berlin, announcing his discovery of a new planet. The latter was at that time busily engaged in organizing a band of German astronomers to search for the planet that should occupy the gap between Mars and Jupiter, where according to the so-called law that bears his name a planet should be. The belief in the validity of this law had recently been strengthened by the discovery of Uranus by Herschel in 1781, thus adding another term to the series, so that astronomers felt justified in making a systematic search for the missing planet. The news of Piazzi's discovery did not reach Bode until March 20th, and although he had continued his observations on into February, by this time his work had been cut short by a dangerous illness, and the planet, which at the time of its discovery was near its stationary point following opposition, had now approached so near the sun as to be invisible, and fears were entertained lest its re-discovery would entail a great deal of difficulty and delay. At this juncture the attention of Gauss was directed to the matter, and the ultimate result was the production of his great work, "Theoria

motus corporum cœlestium." This part of the story had best be told in his own words, quoting from the preface of his book, as translated by Davis. He says:

"Some ideas occurred to me in the month of September of the year 1801, engaged at the time on a very different subject, which seemed to point to the solution of the great problem of which I have spoken. Under such circumstances we not unfrequently, for fear of being too much led away by an attractive investigation, suffer the associations of ideas which, more attentively considered, might have proved most fruitful in results, to be lost from neglect. And the same fate might have befallen these conceptions had they not happily occurred at the most propitious moment for their preservation and encouragement that could have been selected. For just about this time the report of the new planet discovered on the 1st day of January of that year with the telescope of Palermo was the subject of universal conversation; and soon afterwards the observations made by that distinguished astronomer Piazzi from the above date to the 11th of February were published. Nowhere in the annals of astronomy do we meet with so great an opportunity, and a greater one could hardly be imagined for showing most strikingly the value of this problem than in this crisis and urgent necessity, when all hope of discovering in the heavens this planetary atom among innumerable small stars after the lapse of nearly a year, rested solely upon a sufficiently approximate knowledge of its orbit to be based upon these very few observations. Could I ever have found a more seasonable opportunity to test the practical value of my conceptions than now, in employing them for the determination of the orbit of the planet Ceres, which during these forty-one days had described a geocentric arc of only three degrees, and after the lapse of a year must be looked for in a region of the heavens very remote from that in which it was last seen? This first application of the method was made in the month of October, 1801, and the first clear night when the planet was sought for (by de Zach, December 7th, 1801) as directed by the numbers deduced from it, restored the fugitive to observation. Three

other new planets, subsequently discovered, furnished new opportunities for examining and verifying the efficiency and generality of the method."

Gauss' work gives then in addition to the solution of the problem of determining parabolic elements from three observations, also that of the more general problem of determining the form of the orbit without making any assumption regarding the eccentricity; and also the case in which four observations are utilized in computing the orbit.

That three complete observations will in general suffice for the determination of an orbit may be shown in the following manner: If

$$\xi, \eta \text{ and } \zeta$$

are the geocentric rectangular co-ordinates of a heavenly body at any time, they may be expressed in terms of the geocentric distance and longitude and latitude, thus

$$\begin{aligned} \xi &= \rho \cos \lambda \cos \beta \\ \eta &= \rho \sin \lambda \cos \beta \\ \zeta &= \rho \sin \beta ; \end{aligned}$$

and if X, Y and Z be the co-ordinates of the sun, then the heliocentric co-ordinates of the heavenly body x, y and z are given by the equations:

$$\begin{aligned} x &= \xi - X \\ y &= \eta - Y \\ z &= \zeta - Z \end{aligned}$$

Then as x, y and z are functions of the six elements it follows that a single observation giving the latitude and longitude of the heavenly body will give three equations containing seven unknowns — the six elements and the geocentric distance. An additional observation will add another geocentric distance to the number of unknowns, and will increase the number of equations to six; while a third observation will make both equations and unknowns nine in number, and will thus afford a complete solution of the problem.

An exception to this statement, however, will be found in

the case of a heavenly body moving in the plane of the ecliptic. In this case the longitude of the node and the inclination both vanish, so that only four elements remain to be determined. On the other hand the three vanishing latitudes cannot be regarded as independent data, so that a fourth longitude must be observed in order to give a determination of the orbit.

Although it will never be found in practice that an orbit plane will exactly coincide with that of the ecliptic, still, as orbits are met with having all inclinations it is evident that as the inclination approaches the vanishing point the elements will become more and more difficult to determine with precision from three observations, as the unavoidable errors of observation have then an increasing effect; and recourse must be had to four observed positions.

When a new comet is discovered it is observed as frequently as possible, and its position determined; then when a sufficient number of observations have been accumulated its orbit is computed on the assumption that it is a parabola. This assumption is made for several reasons. In the first place the eccentricity of a cometary orbit is always large, so that for a few days or even weeks its path will deviate very little from the parabolic form, and observations extending over a limited time will seldom serve to determine elliptic elements with any approach to precision. In addition, parabolic elements are calculated with comparative ease and in a short time, and will serve to compute an approximate ephemeris by means of which the motion of the comet may be followed, and also to give approximate values of certain quantities which are useful in the after computation of the true orbit. On the other hand the computation of elliptic elements is much more laborious, and sometimes cannot be effected from three positions, but the computer is obliged to make use of four for their determination.

By assuming that one of the elements of the orbit, the eccentricity, is known, only five remain to be determined, so that three complete observations will furnish more data than are necessary for their determination. A complete observation gives

the right ascension and declination of the comet at an observed instant of time, which merely serve to fix the direction of the straight line drawn from the point of observation to the comet, with regard to certain reference planes. As a straight line may be taken to be the intersection of two planes, it follows that a complete observation may be assumed to determine two planes which, by their intersection give the direction of the comet at a given instant. In computing a parabolic orbit then it is assumed that one of the observations, usually the middle one, is incomplete, or that it determines only a single plane containing a position of the comet. The choice of this plane is quite arbitrary, and in Olbers' method it is so chosen as to pass through the centre of the sun at the same instant. In this way the formulæ used in computing the orbit are much simplified, and the computation thus considerably shortened. Unfortunately, however, Olbers' method is in some cases quite inaccurate, and some writers give an investigation by which to determine the position of the plane containing the middle position of the comet which will give the most accurate determination of the orbit; obtaining at the same time a criterion, which may be applied at the outset of the computation, by which to judge whether Olbers' method should be discarded in favor of the longer and more accurate method.

In computing elliptic elements also from four observed positions the same course is followed as that just outlined; *i, e.* two of the observations are assumed to be incomplete, usually the two middle ones, and planes are taken containing those positions of the comet, which will give the most accurate determination of the orbit.

The formulæ used in computing parabolic elements are based upon the following:

$$6\,k\,(t_1 - t_0) = (r_1 + r_0 + s)^{3/2} - (r_1 + r_0 - s)^{3/2}$$

(which is Euler's equation above referred to)

$$x_1 = \rho_1 \cos(\lambda_1 - \Pi)\cos\beta_1 - R_1 \cos(L_1 - \Pi)$$
$$y_1 = \rho_1 \sin(\lambda_1 - \Pi)\cos\beta_1 - R_1 \sin(L_1 - \Pi)$$
$$z_1 = \rho_1 \sin\beta_1$$

$$x_i = \rho_i \cos(\lambda_i - \Pi) \cos \beta_i - R_i \cos(L_i - \Pi)$$
$$y_i = \rho_i \sin(\lambda_i - \Pi) \cos \beta_i - R_i \sin(L_i - \Pi)$$
$$z_i = \rho_i \sin \beta_i$$
$$r_1^2 = x_1^2 + y_1^2 + z_1^2 \qquad r_i^2 = x_i^2 + y_i^2 + z_i^2$$
$$s^2 = (x_i - x_1)^2 + (y_i - y_1)^2 + (z_i - z_1)^2$$
$$\rho_i = m + M\rho_1$$

We have here eleven equations between the eleven unknowns

$$r_1, r_i, s, x_1, y_1, z_1, x_i, y_i, z_i, \rho_1 \text{ and } \rho_i$$

so that they evidently contain a solution of the problem, though not a direct solution. The formulæ used in practice, though derived from these, bear very little resemblance to them; but they will serve to illustrate the method of trial and error which is always used in computing orbits. The expressions for m and M contain among other quantities the ratios of the triangular areas contained by the radii-vectores and the chords joining the observed positions of the comet in its orbit. Their values, therefore, cannot be determined accurately until the orbit is known; they can be found approximately, however, from the intervals between the observed times, which are proportional to the sectorial areas, according to Kepler's second law.

If now a value be assumed for ρ_1 we may compute the corresponding value of ρ_i by means of the last of the above equations; then we may find the heliocentric co-ordinates x_1, y_1, z_1 and x_i, y_i, z_i and then r_1 r_i and s; and from these the value of the right-hand member of Euler's equation, which may be compared with the known quantity $6K(t_i - t_1)$, which depends upon the observed times t_i and t_1 of the two extreme observations and the constant K. If they do not agree, which is more than probable, another trial must be made; and this process must be continued until an agreement is reached between the two members of Euler's equation.

In actual practice the assumed quantity is usually a function of the sum of the heliocentric distances r_1 and r_i, and from this by means of a series of equations the values of r_1 and r_i

are computed separately, whose sum can then be compared with its assumed value. A new trial is then made if necessary. This procedure is then carried on until a sufficiently close agreement is effected between the initial and final values of the sum $r_1 + r_3$.

Having thus determined the values of r_1 and r_3, the radii-vectores of the comet at the first and third observations, the computation of the elements then follows directly by means of a series of equations that need not be reproduced here.

Coming now to the observation themselves, the usual method of determining the position of a comet is by means of a telescope equatorially mounted and provided with a position micrometer. The telescope is pointed to the comet and so directed and adjusted that the transverse thread is a little in advance of the comet and coincides with a declination circle. The time of transit of the comet over the thread is recorded, and at the same time it is bisected by the micrometer thread. A neighboring star is also observed in the same way. Then the difference of the sidereal times of transit of the two bodies is their difference of right ascension, and the difference of the micrometer readings gives their difference of declination, so that if the right ascension and declination of the star are known, those of the comet follow from them. The star may evidently be observed before the comet.

Such differential determinations of position may be very readily made, and may be multiplied rapidly. The only instrument, however, which the writer found available was a geodetic theodolite, so that he was obliged to resort to absolute determinations by observing altitudes and azimuths. The following description of the method pursued will make it appear in sharp contrast with the simple method above described.

An observation with this instrument consisted in pointing to the comet, recording the time shown by a clock, then reading the two circles of the instrument and the striding and latitude levels. Readings of the barometer, with its attached thermometer, and a detached thermometer, were also taken, to be used in computing refraction. In order to determine the altitude and azimuth of the comet from the circle readings, a knowledge of

the zenith reading of the vertical circle, and the meridian reading of the horizontal circle, are necessary. Moreover, the vertical circle reading must be corrected so as to reduce it to the mean state of the latitude level ; and corrections must be applied to the horizontal circle reading for level and collimation errors. As the instrument was kept set up on a substantial pier during the observations, the zenith reading was determined once for all, by taking meridian vertical circle readings on stars for determining latitude, the observations being taken, and the reduction made, in such a way as to bring out the zenith reading as a by-product. The meridian reading was first found approximately by means of a single pointing to a circum-polar star, noting the time of pointing by a chronometer whose correction was known ; and then finding a correction to this approximate value by observing meridian transits of stars for determining time, which also gave the azimuth and collimation constants of the instrument.

Having thus found the altitude and azimuth, the declination and hour angle are next computed — the latitude being known — by a solution of the astronomical triangle. The right ascension then follows by subtracting the hour angle from the sidereal time of observation. Thus the apparent right ascension and declination corresponding to each observation are found.

The positions of the comet thus determined, whether arrived at by the differential or the absolute method, are each referred to the equator and equinox of the epoch of the observation, and before they can be used in computing an orbit they must all be referred to the same equator and equinox. Those usually chosen are the mean equator and equinox of the beginning of the year in which the observations are taken. This necessitates correcting the above apparent places for precession and nutation.

These reductions having been made, the final step in the preparation of the data is the transformation of the declinations and right ascensions into latitudes and longitudes.

There are two further corrections, however, to which reference has not yet been made, and which must be taken account of

in some way, viz. the corrections for parallax and planetary aberration. These are functions of the comet's distance, and, therefore, their amounts cannot be determined unless the computer has, at least, an approximate knowledge of the comet's orbit. This may be the case if he is engaged in computing elliptic elements, and there are available parabolic elements previously computed. The observed positions, whether given by their altitudes and azimuths, or their right ascensions and declinations, may then be corrected for parallax in the usual way. Allowance may also be made for planetary aberration by utilizing the principle, that the apparent place of a comet at the instant of observation is the same as the true place at the instant at which the light left the comet which reached the observer at the instant of observation. Each observed time must then be diminished by the interval of time which light takes to traverse the distance between the comet and the observer.

If, however, the orbit is quite unknown the direct application of a correction for parallax may be avoided by employing the "fictitious place," which is the point in which the line joining the comet to the point of observation, if produced, intersects the plane af the ecliptic. It is clear that an observation, if taken from such a point, would be the same as an actual observation taken from a point on the earth's surface. The reduction to the fictitious place involves the correction of the sun's longitude and radius vector, and the date of observation.

With regard to planetary aberration, in the case of the orbit of an entirely unknown body, the procedure is to carry on the computation to the point where the geocentric distances are determined; these may then be used to determine the effect of aberration, and corrections may then be applied to the quantities affected by it.

Observations of Halley's comet by the method above described were taken on the following dates: May 4th, 10th, 27th, 28th, and 29th, June 3rd, 4th, 8th and 9th.

From the observations taken on May 28th, June 3rd and 9th, the following parabolic elements were computed, using first

Olbers' method, and then the alternative method, in which the plane containing the middle position of the comet is so chosen as to give the most accurate determination of the orbit. Crommelin's elliptic elements are also given for comparison.

	Parabolic Elements		Elliptic Elements
	Olbers' Method	Alternative Method	
T	Ap. 25·91	Ap. 20·54	Ap. 19·67
ω	132 25 11	113 45 51	111 42 16
Ω	60 27 01	57 18 58	57 16 12
i	162 58 51	162 16 29	162 12 42
q	0·763541	0·597245	0·58720
e			0·967281
$\log a$			1·253986

After computing parabolic elements by Olbers' method a criterion was applied showing the relative accuracy of that method as compared with the other, and it was found to be represented by the number 0·05. The computations were then repeated, using the more accurate method, with the above result. Oppolzer advises the abandonment of Olbers' method if the number found as above indicated is less than 0·5.

An attempt was then made to compute elliptic elements from the same three observed positions; it was found at the outset, however, that from geometrical considerations it was impossible to compute elliptic elements from those positions with any approach to accuracy. This arose from the fact that the three positions lay nearly upon the same great circle of the celestial sphere, and this fact was determined by computing a quantity, denoted by K', which is a function of the latitudes and longitudes of the comet, and which may be defined as the product of the sine of the geocentric arc described by the comet between the first and third positions, by the sine of the perpendicular let fall upon that arc from the middle position. If K' is small, in spite of the fact that the arc joining the first and third positions is large, then the middle position must lie nearly upon that arc; and it is clear that in that case small errors of observation in determining the positions of the comet will have an important effect upon the form of the orbit computed from those positions.

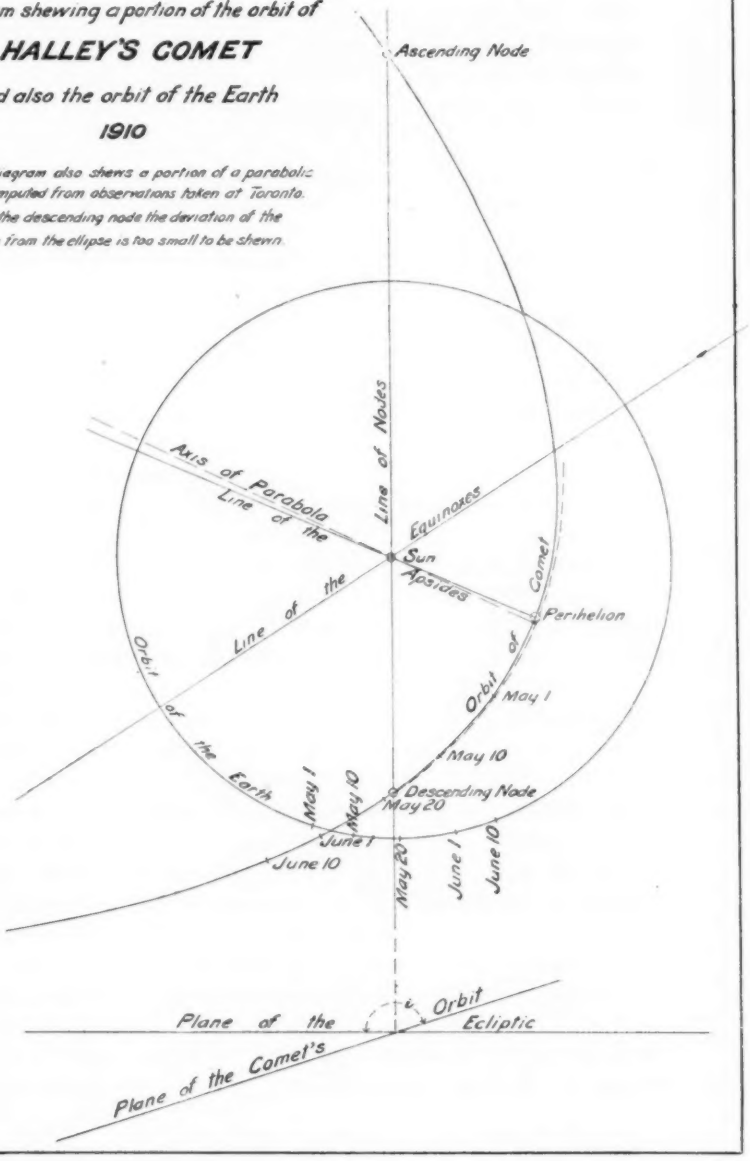
Diagram shewing a portion of the orbit of

HALLEY'S COMET

and also the orbit of the Earth

1910

The diagram also shews a portion of a parabolic orbit computed from observations taken at Toronto. Beyond the descending node the deviation of the parabola from the ellipse is too small to be shewn.



The only course under these circumstances, is to use four observed positions; and the computation of elliptic elements from four positions is now in progress, but is not yet complete.

The annexed diagram shows a portion of the orbit of the comet, in its relation to the earth's orbit, constructed from the above elliptic elements, and also the parabolic orbit given by the second set of computed elements. Beyond the descending node the divergence of the parabola from the ellipse is too small to be shown. The diagram also shows clearly that the assumption of the parabolic form for the orbit is principally responsible for the errors in the values of the angle ω and the perihelion distance, and hence in the time of perihelion passage.

THE SPECTROSCOPIC BINARY 7 CAMELOPARDALIS

By W. E. Harper

THIS star, $\alpha = 4^h\ 49^m{\cdot}3$, $\delta = +\ 53^\circ\ 35'$, photographic magnitude about 4·6, was announced as a spectroscopic binary by Campbell and Moore in 1907.* Work was commenced on the star here in December, 1908, and continued till March of the present year when forty-four spectrograms in all had been secured.

The first eight plates were made with the single-prism instrument as first constructed, linear dispersion at H_γ being 30·2 tenth-metres per millimetre, and the remaining number with the new instrument whose dispersion at the same region is 33·4 tenth-metres per millimetre. Somewhat over a year ago a solution was made from the thirty-nine plates then secured and elements agreeing very closely with the present ones were obtained. Some slight irregularities in the curve seemed to indicate the presence of a second spectrum, and five fine-grained plates have since been made at the crests of the curve for the sole purpose of deciding this question. On plate 3555, which is weak, the *Mg.* line λ 4481 might be suspected as a double, but none of the other plates show any evidence whatever of the presence of the second spectrum.

This star is of type A_2, Harvard classification, and has lines well adapted for measurement. Among the most frequently used were λλ 3933, 4101, 4233, 4340, 4481, and 4549. Many other lines, mostly metallic, were present and when measured gave velocities in good agreement with the principal lines.

The following table contains the data of the measures. The phases are reckoned from periastron passage J. D. 2418281·176, using the period 3·8846 days. The residuals in the last column are scaled from the curve representing the final elements.

* *Astrophysical Journal*, Vol. XXVI., p. 292.

MEASURES OF 7 CAMELOPARDALIS

Plate	Julian Date	Phase	Velocity	No. of Lines	Weight	O − C
1997	2418278.649	1·358	+ 21·7	5	4	− 2·9
2013	285·591	·530	− 13·8	2	1	− 2·8
2043	294·628	1·798	+ 21·8	5	5	− 0·7
2052	297·578	·864	+ 3·3	7	5	− 4·2
2089	313·514	1·261	+ 25·0	7	6	+ 2·2
2137	322·542	2·520	− 4·1	2	2	+ 4·9
2222	341·480	2·035	+ 19·1	4	5	+ 3·9
2248	346·539	3·209	− 40·1	5	4	+ 0·4
2338	374·664	·258	− 25·0	5	5	+ 0·5
2409	388·645	2·585	− 11·9	5	5	+ 0·6
2507	420·616	3·479	− 49·1	2	2	− 4·6
2519	423·633	2·611	− 15·5	3	2	− 1·3
2835	580·683	·393	− 16·6	3	5	+ 2·2
2843	584·770	·601	− 5·0	6	5	+ 2·2
2856	586·652	2·477	− 12·6	4	4	− 6·1
2872	588·707	·648	− 6·1	7	6	− 1·6
2909	600·920	1·207	+ 29·1	1	1	+ 7·8
2950	623·851	·830	+ 1·5	5	5	− 4·5
2975	637·591	2·916	− 26·4	6	6	+ 3·6
2992	642·552	·108	− 31·9	7	7	+ 0·6
3066	670·660	1·024	+ 9·0	4	4	− 6·0
3075	671·614	1·978	+ 13·2	7	7	− 3·8
3080	672·611	2·975	− 27·5	3	2	+ 5·0
3093	682·595	1·305	+ 25·0	9	5	+ 1·2
3098	684·561	3·271	− 39·8	4	4	+ 2·3
3111	686·769	1·595	+ 29·3	7	7	+ 3·7
3125	687·795	2·621	− 16·9	8	7	− 2·4
3138	691·619	2·560	− 10·3	4	4	+ 0·7
3154	700·586	3·758	− 43·1	7	6	− 2·1
3157	703·542	2·829	− 22·5	5	4	+ 3·7
3185	717·506	1·255	+ 24·4	5	6	+ 1·6
3191	719·583	3·332	− 40·2	4	3	+ 2·9
3195	721·540	1·410	+ 24·2	4	4	− 1·0
3204	724·657	·636	− 4·0	5	5	+ 0·7
3207	726·521	2·500	− 7·3	5	4	+ 0·7
3246	731·607	3·702	− 45·5	6	5	− 3·5
3254	733·570	1·780	+ 21·3	4	3	− 1·9
3295	740·646	1·087	+ 21·7	6	4	+ 4·2
3339	749·523	2·194	+ 2·9	9	8	− 5·1
3555	886·853	3·564	− 48·0	2	1	− 3·8
3561	892·790	1·732	+ 20·5	4	3	− 3·2
3608	8915·882	1·516	+ 28·2	2	2	+ 2·2
4058	9102·607	1·780	+ 28·1	4	5	+ 5·1
4079	9104·647	3·820	− 43·4	3	3	− 3·0

Through the kindness of Professor Campbell, the G.M.T. of the Lick plates were obtained and for completeness those observations are given here.

LICK OBSERVATIONS

Date		Julian Date	Phase	Velocity	O – C
1902 November	4	2416058·987	3·687	– 36·5*	+ 6·0
1903 December	6	6455·971	·557	– 18·5*	– 9·2
1907 February	7	7614·721	1·696	+ 20·5	– 4·4
"	27	7634·694	2·246	– 3·2	– 8·7
March	13	7648·724	·738	1·8	2·6
April	22	7688·692	1·860	+ 22·5	+ 1·5
August	8	7796·976	1·375	+ 23.	– 2·0

* Means of two approximate measures.

There is some uncertainty as to the exact period. Our own observations gave the value 3·885 days, and when the Lick observations were used in conjunction with our own a period of 3·8848 days was obtained. This satisfied all their observations well except the second which had a residual of −15 km. As the agreement of the two approximate measures made on this plate seemed to make it trustworthy it was thought best to equalize the residuals by changing the period to 3·8846, and this is the value here accepted.

The observations were now grouped into sixteen normal places, the weights assigned each group being in general one-tenth of the sum of the weights of the individual plates comprising the group.

NORMAL PLACES

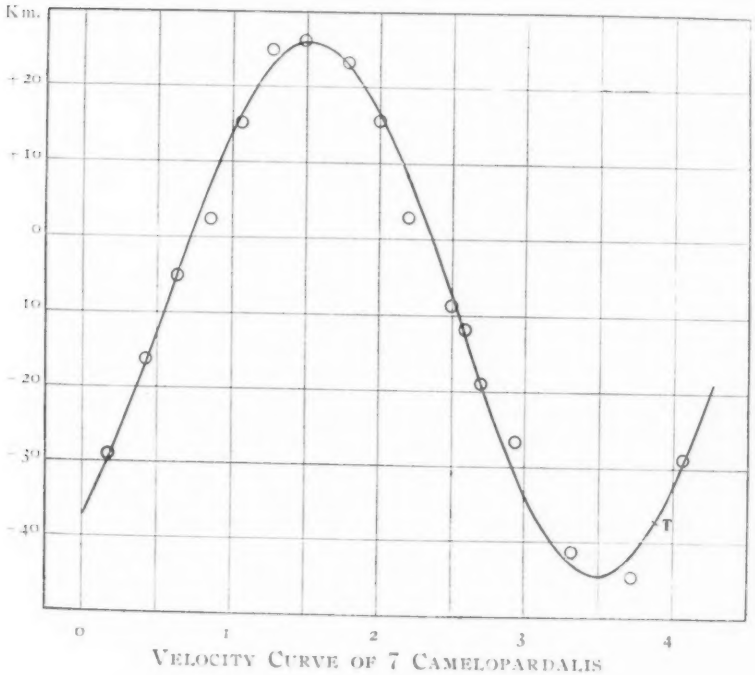
	Mean Phase	Mean Vel.	Wt.	O – C		Mean Phase	Mean Vel.	Wt.	O – C
1	·170	– 20·02	1·0	+ 1·29	9	2·002	+ 15·66	1·0	– ·95
2	·416	– 16·13	·5	+ 1·29	10	2·194	+ 2·90	·5	– 5·45
3	·630	– 5·10	1·5	+ ·03	11	2·495	– 8·78	1·0	– 1·20
4	·847	+ 2·40	·8	– 4·31	12	2·581	– 11·97	1·0	+ ·42
5	1·055	+ 15·35	·7	·80	13	2·697	– 18·94	·9	– ·15
6	1·268	+ 25·03	2·0	+ 2·22	14	2·931	– 26·67	·6	+ 3·90
7	1·486	+ 26·19	2·0	+ ·42	15	3·311	– 41·25	1·5	+ 1·01
8	1·777	+ 23·43	2·0	+ ·17	16	3·717	– 44 65	1·5	– 2·50

Preliminary values of the elements were obtained by Dr. King's graphical method and then a least-squares solution was made. As the eccentricity was small the time of periastron passage was taken as fixed and a value of ω assumed so that only the four elements γ, K, e and ω entered into the solution. The following table gives the results of the solution.

ELEMENTS OF 7 CAMELOPARDALIS

Elements		Graphical	Corrections	Final Values
Period	P			3·8840 days
Eccentricity	e	·00	+ ·013	·013 = ·020
Long. of Apse	ω	218°·45	− 1°·31	217°·14 = 1°·20
Half amplitude	K	35·00 km.	+ ·15 km.	35·15 km. = 0·72 km.
Vel. of system	γ	− 9·20 "	+ ·27 "	− 8·93 " = 0·51 "
Periastron passage				J. D. 2418281·176
	A			34·79 km.
	B			35·51 "
	$a \sin i$			1,877,000 "

The sum of the squares of the residuals for the normal places was reduced from 77·6 to 68·5 and satisfactory agreement was obtained between equation and ephemeris residuals, the greatest difference being 0·03 km. The probable error of a plate



VELOCITY CURVE OF 7 CAMELOPARDALIS

obtained from columns six and seven of the table of measures is ± 2·18 km. per sec.

The curve shown represents the final elements.

While the irregularity in the curve is still noticeable the three normal places which show it most have weights below the average and the peculiar trend of the residuals might be treated as accidental. The writer, however, is rather inclined to believe that the second spectrum is present, and, though faint, has sufficient influence on the measures to account for the deviations shown.

DOMINION OBSERVATORY,
OTTAWA, CANADA,
April, 1911.

ECLIPSE CYCLES

By W. H. S. Monck

ECLIPSE Cycles, to which the ancients attached great weight. have lost much of their importance since future eclipses have been computed beforehand for a great number of years with an accuracy that no cycle can give. Nevertheless the interest in them is not merely historic. We can often decide by means of a cycle some question as regards past or future eclipses, information regarding which is only to be found in treatises known to few and not easily available. I will give an illustration. The historian Dr. Lingard tells us that there was an eclipse of the sun on the morning of the battle of Cressy — August 26, 1346. Was this so? There is a cycle of 521 Julian years which is a pretty reliable one — at all events as regards new moons, if not solar eclipses. The new moons and full moons of 1346 would therefore reappear in 1867, subject only to the Gregorian correction of the calendar — 12 days. A new moon on August 26, 1348, would thus imply a new moon on September 7, 1867. I happened to have the *Monthly Notices* of the Royal Astronomical Society for 1867. I referred to them. I found there an account of a lunar eclipse on September 13, 1867. This, of course, rendered a new moon six days previously impossible. If there was an eclipse of the new moon nearest to the battle of Cressy it took place nine days before that event. This is very probable. When eclipses were regarded as portents, tradition almost always represented them as nearer the event than they actually were. Of this there are numerous examples.

The reader is no doubt aware of the general outline of the theory of eclipses. The planes of the orbits of the sun and moon do not coincide, and it is only when the sun is pretty near one of the nodes at full moon or new moon that an eclipse can occur. But the nodes are not fixed. They have a revolution of their

own, and eclipse-cycles turn on near coincidences between a whole number of revolutions and a whole number of lunations. Supposing that we could get figures which represented this relation accurately, then starting from an eclipse when the sun was at the node at full moon (or at new moon if we started from a solar eclipse) it would be again at the node at full moon when the cycle was completed. But we cannot get exact whole numbers for this purpose and must be satisfied to approximate. The Chaldean Saros, which I may call Cycle No. 1, gave 19 revolutions of the nodes (in relation to the sun) = 223 lunations. The latter were accomplished on the average in 6585·32 days, the former in 6585·78 days. If the first eclipse were at the node this difference of 0·46 days would not prevent a return of a lunar eclipse until the number of returns reached about 23, *i. e.*, till the sun was 12 days' journey from the node at the date of the full moon. If we chanced to start with the first eclipse of the series the Saros would give us usually 47 to 50 successors; but if we hit upon an eclipse at the other end of the scale it might fail us at once. A total eclipse of the moon was, however, certain to have successors, for the eclipses computed according to the Saros would become partial for some time before they finally died away.

I do not know how far the ancients were aware that if a whole number of semi-revolutions of the node were equal to a whole number of lunations, starting from an eclipse wewould likewise end with an eclipse, although perhaps at a different node from the first one. At all events they do not seem to have transmitted to us any such cycle, though one was not far to seek. Twenty-three semi-revolutions of the nodes correspond to 135 lunations almost as accurately as 38 semi-revolutions coincide with 223 lunations (the Chaldean Saros). The figures are in this latter case 23 semi-revolutions = 3986·13 days; 135 lunations = 3986·63 days: difference 0·50 days. I call this Cycle No. 2. It will be noted that while the revolutions in Cycle No. 1 require about 0·46 of a day more than the corresponding number of lunations, the difference is here in the opposite direction — a fact which has some

important consequences. The period 3986 days is 11 years less by 30 or 31 days—a kind of uncertainty which is unavoidable because the number of leap-years in 11 years is not fixed. Roughly speaking the eclipse occurs a month earlier after a lapse of 11 years.

I noted that starting from a given eclipse we can not predict with certainty a single return in accordance with the Saros, for the difference of 0·46 of a day might take us from a position within the eclipse limits to one without them. The same remark applies to Cycle No. 2, where the difference is 0·50 of a day. But it is evident, at all events, that there must always be an eclipse either in accordance with Cycle No. 1 or with Cycle No. 2, for if we are within 0·46 or 0·50 day's journey of one end of the ecliptic limits we can hardly be less than 20 days' journey from the other end. And if we found that the eclipse with which we were starting had a predecessor in accordance with Cycle No. 2 we may safely predict a successor in accordance with Cycle No. 1; for we know that we would still be within the ecliptic limits after 0·50 day's journey in a direction in which we are only required to travel 0·46 day's journey. The converse is not certainly true. Although 0·46 day's journey in the intended direction would leave us still within the ecliptic limits 0·50 day's journey might take us outside of them. But suppose we have two predecessors in accordance with Cycle No. 1, we can safely predict one successor in accordance with Cycle No. 2; for the ecliptic limits extend for at least 0·92 day's journey in the direction in which we have only to travel 0·50. And if we found by past records that there had been ten preceding eclipses in accordance with Cycle No. 1 we could predict nine in accordance with Cycle No. 2; for this would only take us back 4·5 days' journey in a direction where the ecliptic limits must be farther than 4·6 days' journey.

An eclipse in accordance with Cycle No. 1 will commence at the ecliptic limit on the far side of the node, then gradually approach the node, pass it, and go on to the ecliptic limit on the other side where it will finally disappear. This process will be

completely reversed in the case of Cycle No. 2. The current mode of speaking of an eclipse as appearing, returning a number of times, and finally disappearing, is misleading. In the strict sense an eclipse never returns. What is called a return is the arrival of a successor in accordance with a cycle — usually the Saros. But we cannot describe the eclipse as finally dying out unless we assume that there is only one cycle to be considered. From what has been said it is evident that when the series of eclipses in accordance with Cycle No. 1 comes to an end, we are in best position for commencing a new series in accordance with Cycle No. 2. If the former series has contained 50 eclipses (which is about the usual number) the new series will contain about 46; and then we shall be in a good position to start a new series in accordance with Cycle No. 1. If the corresponding numbers were commensurate we could go on in this way forever, but even as it is the earth will probably cease to be inhabitable by the time that the various series based on fifty eclipses in accordance with Cycle No. 1 would fail us. (But of course they would not enable us to predict *all* eclipses during the period which they cover). The reader will no doubt have already noticed that a very accurate cycle may be arrived at by combining Cycles No. 1 and No. 2, viz., 61 semi-revolutions of the nodes = 358 lunations. The period is here 29 years less by 20 or 21 days. Sixty-one semi-revolutions are effected in 10571·91 days, while 358 lunations occupy 10571·95 days. The difference is less than one-tenth of that in Cycle No. 1 and the entire series embraces not 50 eclipses but over 500. I may designate this Cycle No. 3. Starting from an eclipse which has a predecessor in accordance with Cycle No. 1 we can safely predict 10 successors in accordance with Cycle No. 3. And if we can find a second predecessor in accordance with Cycle No. 1 we may double the number of successors in accordance with Cycle No. 3. It will be seen that this Cycle also gives pretty nearly a whole number of days so that two or more successive eclipses in accordance with it are likely to be seen in the same locality.

The period in this Cycle in Julian years is very nearly $28\frac{17}{19}$.

and 18 terms of it give a period of 521 Julian years which we often find verified in eclipses. Thus Mr. Johnson in his little work on "Historical and Future Eclipses" mentions historical eclipses on June 16, A.D. 364, 885 and 1406, and predicts a future eclipse on June 29, 1927, the Gregorian correction of the calendar for the period amounting to 13 days. The error in this Cycle of 521 Julian years is somewhat greater than in the Saros, but it would probably hold good (if we commence with the earliest eclipse of the series) for nearly 30 returns or a period of 15000 years.

Cycle No. 3 is, as I have pointed out, a compound Cycle. But why not use a more genuine compound embracing a large number of eclipses by taking terms from Cycle No. 1 and Cycle No. 2 alternately? And if we adopted this course we could make our composite Cycle more accurate by occasionally throwing in an extra term from Cycle No. 1. The best arrangement would, I believe, be to insert this extra term at Nos. 25, 50, 75, etc., all the other terms being taken alternately from Cycle No. 1 and Cycle No 2. Such a composite cycle might be carried to a great length and very few eclipses would escape the net.

In all these Cycles the period given are those from one lunar eclipse to another or from one solar eclipse to another, but do not connect solar with lunar eclipses. I have been chiefly considering lunar eclipses in the figures given. The solar ecliptic limits being wider than the lunar all three Cycles can be relied on for a larger number of returns when applied to solar than to lunar eclipses. But for this reason solar eclipses are more numerous than lunar and an accurate formula for the time between the former and the latter is hardly to be expected. Observing a solar eclipse does not give one much assistance in predicting a lunar eclipse, but the observation of a single lunar eclipse enables us to predict several solar eclipses with absolute certainty. The solar ecliptic limits being wider than the lunar, the mere fact that an eclipse took place at a certain full moon will enable to predict that at a future new moon the sun will be within the ecliptic limits. The time from a lunar to a solar eclipse must be an odd

number of semi-lunations. The Saros equation divided by 2 becomes 19 semi-revolutions of the node = 223 semi-lunations. The difference there is only 0·23 days, and that cannot take us from a portion within the lunar ecliptic limits to one outside of the solar ecliptic limits. In about 9 years and 5 days (leap-years may make a difference of a day or two) after an eclipse of the moon there must be an eclipse of the sun. And, in fact, this eclipse of the sun must take place so well within the solar ecliptic limits that I think we might go on to predict 30 or 40 solar eclipses in accordance with Cycle No. 3. Certainly we could predict some future eclipses in accordance with all three cycles, using the predicted solar eclipse (not the present lunar eclipse) as the starting point of the cycle.

How far are these cycles reliable, *e. g.* how far, if I have a complete list of the eclipses from 1st January, 1881, to December 10th, 1909, can I rely on all the eclipses from December 10th, 1909, to November 29th, 1938, occurring in accordance with Cycle No. 3? Let us take lunar eclipses which return less frequently than solar. The number of these in the period 29 years less by 20 or 21 days is usually about 48. But each lunar eclipse returns at least 500 times if treated by Cycle No. 3, and we may fairly assume that the 48 eclipses which occurred in the period in question were not, on the average, more than half-way through there course and had, on the average, 250 returns to make. The chances against any of them disappearing in the next period are, therefore, at least 5 to 1, and the chance against a new eclipse appearing is equally great. The probability, therefore, is that the lunar eclipses of the former period will be simply repeated without change in the latter though the chance of a change is not altogether negligible. The solar eclipses would have exhibited a still greater probability of simple repetition.

I may remark that if a cycle is a fairly good one two eclipses could not disappear on the same turn, nor could two new eclipses appear. Take the Saros For two eclipses to disappear on the same turn both must on the preceding turn have been within 0·46 day's journey of the same eclipse-limit. Consequently the

interval between the occurrence of the two eclipses would form a term of a cycle with a shorter period and less error than that which we were adopting. Suppose, for instance, that we were trying a period of 58 years less by 41 days we would very probably find that two eclipses disappeared simultaneously and that the interval between them was 29 years less by 20 or 21 days; but this would be enough to substitute the latter cycle for the former. (Whether, however, a solar eclipse and a lunar eclipse might not disappear on the same turn is a point on which I offer no opinion). The prediction of solar eclipses would, as I already remarked, be still more accurate. There can be little doubt that, with a table of all the eclipses for the last 29 years before us, we could predict the eclipses of the next 29 years with almost perfect accuracy. We would probably not make more than one error or omission in a list of about 115 eclipses.

The number of eclipses comprised in any of these cycles does not appear to be constant, which is, of course, inconsistent with absolute accuracy. That in the Saros is usually 29 lunar and 41 solar; in Cycle No. 3 it may be taken as 48 lunar and 66 solar. This last cycle may, perhaps, explain a cycle of eclipses mentioned by Plutarch. It consisted of 465 eclipses of which he describes 404 as 6-monthly and 61 as 5-monthly. He seems to be speaking of solar eclipses only and the number of these in 7 terms of Cycle No. 3 would be about 465, but I have not determined the degree of accuracy. There are 2 solar eclipses every year which might be called 6-monthly eclipses but "5-monthly" is a very inaccurate designation for the remaining eclipses. Still we may, perhaps, understand him as meaning by 5-monthly eclipses, the eclipses other than the regular two per annum which are caused by the shortness of the lunar year and of the revolution of the lunar nodes. If so 404 6-monthly eclipses would indicate a period of 202 years. Now 7 terms of Cycle No. 3 make 202 years and about 223 days. But the numbers apparently ought to be 405 and 60 instead of 404 and 61 if I have hit upon Plutarch's meaning.

From a single lunar eclipse we can predict a solar eclipse at

a nearer date than I have mentioned although so many successors cannot, in this case, be relied on. Four semi-revolutions of the node — two eclipse-years as some astronomers designate them — amount to 693·24 days, while 23½ lunations amount to 693·97. The difference, 0·73 days, is greater than in Cycles 1, 2 and 3, but it is not large enough to permit the sun to change from a point within the lunar ecliptic limits to one outside of the solar ecliptic limits; and, therefore, given the lunar eclipse, a solar eclipse must follow in 694 days. And I may remark that if we compute a solar eclipse from a lunar one by the formula 4 semi revolutions = 23½ lunations and find the next solar eclipse by the Saros, we shall get the very same solar eclipse as if we started with the period of 9 years and 5 days (111½ lunations) and used Cycle No. 2 to ascertain the second solar eclipse. The eclipse occurs at the end of 246½ lunations from the original lunar eclipse and will never fail to make its appearance. It is worth noting that the 694 days' solar eclipse will be nearly at the same hour as the original lunar one.

I might dwell farther on the subject but some of my readers may think that I have given it too much space already, while those who feel interested in it can pursue it farther for themselves.

NOTE ON THE CLASSIFICATION OF THE CHEMICAL TYPES OF STARS

By W. Balfour Musson

THE accompanying table, which is based upon the Catalogue of Stellar Spectra of the Harvard College Observatory, illustrates the comparative strength of the lines of hydrogen, and calcium, together with the solar lines, and λ4481·4 of magnesium, in the chemical types of stars, and may be taken to represent a gradual transition in a process of development depending mainly upon increasing density and the influence of convection currents. As the transition is very gradual there is necessarily some overlapping in the comparison of the first with the following columns, but the arrangement will, I believe, be found to be approximately correct.

In a paper "On the Photographic Spectra of Stars,"* in which the purpose was to determine the "probable sequence in the order of evolution of the different stellar types." Sir Wm. Huggins "selected as a true natural criterion, clearly indicating successive changes of density and temperature, the gradual increase of strength of the calcium line *K*, taken together with the diminution in strength of the lines of hydrogen, and the simultaneous incoming and strengthening of the metallic lines."†

The magnesium line 4481 has been considered of great importance in astrophysics. The fact that this line had only been observed when the spectrum was due to a high tension spark led Professor Scheiner to attribute its presence to a condition of exalted temperature, and from the important place it occupied in the spectra of stars of class I. to assign to these stars a position high in the temperature scale.‡ In fact the prominence of this line was long held to be a criterion of high temperature.

* *Phil. Trans.*, 1880, p. 669.

† *Atlas Rep. Stellar Spec.*, p. 66.

‡ *Die Spectralanalyse der Gestirne*, Professor Frost's Translation, p. vii.

Comparative Table of the Classification of the Chemical Types of Stars

Chemical Types	Harvard Groups	Elements				Solar Lines	*Mg* λ 4481·4
		Hγ	*He*	Ca *H*	Ca *K*		
HELIUM	I., II., III.	Increasing	Increasing	Faint	———	Absent or Faint	Faint
	IV., V.	,,	Decreasing	Gaining	———	Faint	Increasing
	VI.	,,	,,	Prominent	Faint	,,	,,
HYDROGEN	VII.	,,	,,	,,	Prominent	,,	Distinct
	VIII.	Decreasing	———	Doubled in Strength	Increasing	Becoming Prominent	
	IX.	,,	———	Again Doubled	,,	Prominent	
	X.	,,	———	Ten times strength in VII.	,,	,,	
	XI.	,,	———	Again doubled	Equal to *K*	,,	
METALLIC (Solar)	XII.-XIV.	,,	———	Almost Max.	Almost Maximum	Strong	
	XV., XVI.	Steadily Decreasing	———	Maximum	Maximum	Declining	
TITANIUM OXIDE	XVII.	,,	———	,,	,,	,,	
	XVIII., XIX.	,,	———	Declining	Declining	,,	
	XX.	Strong absorption bands of Titanium-oxide.					
CARBON	XXI.	Strong absorption bands of Carbon or Carbon Compounds.					
WOLF-RAYET STARS	XXII.	Bright lines in addition to dark lines and bands.					

Hartmann and Eberhard, however, in the course of some experiments in the spectra of magnesium and silicon, made use of the electric arc under water,* and were surprised to find that certain lines were thus obtained which had hitherto been regarded as characteristic of the spark spectrum, the magnesium line 4481 appearing as one of the strongest in the whole spectrum. Analogous results were obtained with zinc and cadmium. As researches by Crew and Basquin had shown the arc spectrum to be modified in the presence of an atmosphere of hydrogen, the experiment was made of photographing the arc spectra of a series of metals in a current of hydrogen.

The authors say : —

" It now appeared that spectra obtained in this manner are in fact almost identical with the arc spectra under water, and we are, therefore, of the opinion that hydrogen, released by electrolysis around the electrodes in water, causes the transformation of the arc spectrum in the form observed by us."

" It follows from our investigations that it is not permissible to set apart individual lines of the spectra of metals as characteristic of the spark or of the arc respectively, and from their appearance to draw conclusions regarding the temperature of the corresponding processes of luminosity. The latter point applies particularly in the interpretation of stellar spectra, for which some have sought to make positive statements as to the temperature of stellar atmospheres, based upon the behaviour of individual magnesium and silicon lines."

Since stars of the first spectral type are characterized by very heavy hydrogen absorption, the important bearing of these experiments upon the interpretation of the magnesium spectrum in such stars is evident.

For further facts relative to the relationship between arc and spark spectra see Hartmann, *Astrophysical Journal*, Vol. XVII., p. 270 and Huggins, *Ibid*, p. 145.

Astrophysical Journal, Vol. XVII., p. 229.

MEETINGS OF THE SOCIETY

AT TORONTO.

March 7.— The meeting was held in the Physics Building of the University of Toronto.

Mr. L. Gilchrist gave the lecture of the evening on "The Constitution of, and the Condition of the Matter in Stars and Nebulæ." The various kinds of spectroscopes were described and their application to the determination of the different types of nebulæ and stars. The question of their temperature was also discussed, and various experiments were shown illustrative of bright-line spectra, absorption spectra and light produced by fluorescence.

March 21.— Mr. Samual Dillon Mills, Toronto, was elected a member of the Society.

Mr. J. R. Collins reported the observation of a number of meteors radiating from Leo during the period extending from March 14th to the 20th. The meteors were scattered and not numerous, though bright and rapid.

Prof. C. A. Chant gave the lecture of the evening on "Methods and Results of Solar Investigation." The lecturer divided his subject into three parts: (*a*) General interesting features of the sun; (*b*) Methods of investigating the sun; (*c*) Recent results of investigation.

The general appearance and characteristics of the sun were clearly presented, the relations between the photosphere, chromosphere, corona, sunspots and other features were outlined. The chief instruments,— the telescope and the spectroscope,— were

described, a full explanation being given of the spectroheliograph and the uses to which it has been put. The results of some work by Professor Hale, at Mt. Wilson Observatory, were given, but the lecturer dealt more particularly with the notable recent work on the sun by Professor Deslandres, of the Astrophysical Observatory at Meudon, near Paris. On his spectroheliograms some peculiar "filaments" and "alignments" have been detected, and Deslandres suggests an analogy between them and some ripples on the surface of a liquid produced by convection currents when the liquid is heated uniformly from below.

April 1.— A special meeting was held in the Physics Building of the University of Toronto. At the request of the President, who was unavoidably absent, Professor C. A. Chant occupied the chair, and introduced the lecturer of the evening, Prof. G. W. Ritchey, of the Mount Wilson Solar Observatory, California.

The subject of the lecture was "Photographing the Heavens." The various instruments and their accessories used in stellar photography were described. Refracting telescopes were first considered and the history of their development given, illustrated by slides of well known telescopes at the observatories in Europe and America. Also examples of the work obtainable with these telescopes were shown. Then reflecting telescopes were taken up, and the work carried on at Mount Wilson in this connection was discussed in detail, many illustrations being given of the advantages of this type over the refracting telescopes and the advances made by means of the sixty-inch reflector at Mount Wilson.

A hearty vote of thanks, moved by Mr. F. Arnoldi, K.C., seconded by Mr. John A. Paterson, K.C., and supported by G. Parry Jenkins, was tendered to the lecturer.

April 4.— Mr. A. J. Dempster, M.A., 640 Dovercourt Road, Toronto, and Mr. S. Beatty, M.A., University of Toronto, were elected members of the Society.

The President called attention to the fact that the resigna-

tions of the Librarian, Mr. Sinclair and the Assistant-Librarian, Miss Mason, had been received.

Mr. J. R. Collins gave the lecture of the evening on "The Forms and distribution of Nebulæ." The lecturer first gave a general outline of the subject indicating the character and position of nebulæ and the stars with which they seemed to be identified. Then, by the assistance sf slides, various types of nebulæ were shown and their characteristic details pointed out, and maps of the heavens shown to indicate their positions.

The fact that though nebulæ are to be found in every part of the sky, they appear to be most evident in the vicinity of the poles of the Milky Way where the stars are fewest, and thin out towards the galaxy where the stars are more numerous was emphasized as suggestive of some general relation to the galaxy. The apparently diffuse masses like that of the Orion Nebula tend more generally to aggregate towards the equator of the galaxy and the spiral or more advanced forms containing, in many cases, hundreds and even thousands of dark-lined stars in their gigantic whirls are the type most common in the vicinity of the poles of the Milky Way, notably, in the north. In the neighborhood of "Coma Berenices" the diffuse form of the character of the Orion Nebula tend to abound. The distance and proper motions of the nebulæ seem to vary approximately in about the same proportion to that of the stars.

April 18.— The following eighty-two ladies and gentlemen, residents of Guelph and neighborhood, were elected members of the Society. These will organise a new Centre of the Society which will meet at Guelph.

Dr. E. C. Barnes, W. J. Bell, M. S. Bœhm, W. E. Buckingham, H. B. Callender, George Chapman, Rev. G. F. Davidson, J. B. Fairbain, W. H. Hamilton, J. R. Howitt, M.PP., Norman Macdonald, Dr. A. T. Hobbs, Dr. H. Howitt, Dr. H. Orton Howitt, C. E. Freer, J. M. Taylor, Dr. J. Lindsay, Rev. W. G. Wilson, Dr. H. G. Roberts, Colonel A. H. Macdonald, Harry Mahoney, Rev. C. A. Sparling, Colonel John Davidson, R. L. Torrance, D. E. Rudd, R. H. Brydon, Dr. W. F. Savage, J. A.

Scott, J. J. Whaley, Wm. McLaren, H. E. S. Asbury, F. Chenowith, A. J. Renshaw, G. Clifton Thompson, Henry Westoby, Professor W. H. Day, Mrs. W. H. Day, William Tytler, J. McNiece, H. J. B. Leadley, Mrs. H. J. B. Leadley, Miss Mary Mills, Lieut.-Col. D. McCrae, J. Hutcheon, E. Robinson, Samuel Terrell, T. J. Colwill, R. W. Wade, J. Price, J. J. Thomas, Dr. H. C. Skinner, J. J. Drew, R. R. Graham, Dr. G. C. Creelman, Dr. W. O. Stewart, Adam Taylor, F. A. Græsser, J. T. Luton, J. M. Taylor, Jr., J. M. Duff, G. B. Ryan, Dr. Hugh C. McLean, Professor J. B. Reynolds, H. L. Fulmer, Dr. R. Lucy, F. J. Winlow, H. C. Scholfield, J. W. Lyon, G. A. Sleeman, Mrs. T. Cæsar, Professor R. Harcourt, Professor S. B. McCready, E. W. Kendall, G. E. Smith, G. P. McKay, L. D. Jackson, Miss E. C. Dwight, Mrs. R. B. Dwight, Miss Beatrice M. Bethune, Mrs. W. O. Stewart, J. E. Howitt.

Mr. W. Balfour Musson gave a paper on "Stellar Types." Stars were classified from such characteristics as their chemical nature, color; their motions; being single, double or multiple; from their orbits, *e. g.*, the eccentricity of the orbit is related to the particular type. Various theories of origin were considered, including the Laplacian nebular theory, the spiral nebular theory, and the life-history of a star was presented. The unsatisfactory features in the theories of origin and classification were pointed out, particularly that the classifications based on temperature alone are open to much criticism. (See further on page 125).

L. G.

At Ottawa

February 23.—Mr. R. M. Stewart presiding. Mr. J. S. Plaskett read a paper on "Some Recent Interesting Developments in Astronomy." In introducing the paper Mr. Plaskett explained that he did not propose to cover the whole field of astronomy, as that would be quite impossible, but to select the most interesting of the recent important developments. After pointing out the growing interrelation of the sciences and the application of the kindred science in astronomy, he discussed

briefly the recent advances in geophysics, including the development of the theory of isostasy, the application of seismology in determining the constitution of the interior of the earth, and the recent advances in the discovery of magnetic fields around sunspots and its relation to terrestrial magnetism.

He passed then to the great strides made in solar research, as marked at the last meeting of the Solar Union at Mt. Wilson, where the principal advances signalized were : — (1) The adoption of new secondary standards of wave-length correct to within one part in a million. (2) The discovery that sunspots are at lower temperature than the photosphere, that the vapors of compounds are present in them and that finally they are surrounded by magnetic fields as recently so beautifully demonstrated by Professor Hale. (3) The division of the spectrum among six institutions, of which the Dominion Observatory is one, for the determination of the solar rotation by the displacement of the spectral lines at the sun's limbs.

After discussing briefly the perennial question of the objective existence of the fine geometrical markings on Mars and the presence of water vapor in its atmosphere as determined by the presence of the vapor band in its spectrum, the habitality of Venus and the recent appearance of Halley's Comet were dealt with.

A short description of the largest working telescope, the 60-inch reflector, at Mt. Wilson was given, followed by a description of Stebbins's method of measuring the light of stars by the change in the resistance of selenium, with its application to Algol whose light curve was much more accurately determined than ever before, and which was shown though of about the same diameter, to give probably over 200 times as much light as the sun.

The recent advances in Stellar Spectroscopy with especial reference to Campbell's work in determining the direction and velocity of the solar motion through space, and to the great increase in the determination of the orbits of spectroscopic binaries, in which the Dominion Observatory is taking so active a part,

were then dealt with and Mr. Plaskett then passed to the general question of stellar motions.

He pointed out that recent investigations have shown that there are two general drifts of the stars in opposite directions, almost as if our universe consisted of two systems interpenetrating one another. In addition to these drifts the question of star streams was taken up and the Ursa Major streams consisting of the principal star of the Dipper with Sirius and α Coronæ; the Taurus stream of about 40 stars in the Hyades, and the two streams of Orion stars moving in opposite direction at the same rate, so recently discovered by Professor Kapteyn, were described.

Passing to the question of distances of stars it was shown how statistical methods have recently added much to our knowledge of the dimensions of the universe and how the stars are distributed at distances ranging up to thousands of light years away. The lecture was concluded by pointing out that although much had been discovered as to the structure, motions and dimensions of the universe much was yet to be done, but that the problem was not hopeless.

March 9, 3 p.m., at the Observatory.— Mr. F. A. McDiarmid gave a paper entitled "Errors in Field Observations."

Mr. McDiarmid first pointed out the importance of eliminating as far as possible all errors in latitude and longitude observations. Errors may be classified as instrumental, personal and catalogue. The errors of the last class are very small in longitude and azimuth work but are often large in latitude work.

The methods of obtaining longitudes were then treated of and the accuracy of former methods compared with that of those now in use. The importance of the chronograph to record star transits was pointed out and the personal equation of different observers given for both the eye and ear method and the chronographic method of recording transits. The variation of this personal equation owing to differences in the personal condition of the observer led to the introduction of the transit micrometer. Mr. McDiarmid explained the construction and working of this instrument and showed how it almost eliminated personal equa-

tion, and hence the variation of the latter quantity was of much less value.

Another improvement in the work was the introduction of one polar star for azimuth for every two time stars observed, thus increasing the accuracy of the azimuth and consequently giving a truer clock correction. By reversing the instrument in the wyes during observation and observing a star before and after transit the collimation error was eliminated. The value of the level correction and the time correction due to exchanges were now the weak points in the time work, though the latter could be eliminated by securing an uninterrupted wire between stations.

The errors affecting azimuth were then discussed. The errors peculiar to each night were shown to be large in proportion to the errors of a single set. Mr. McDiarmid gave lateral refraction as a plausible explanation.

In discussing latitude work, Mr. McDiarmid showed that personal errors were almost entirely eliminated, that no error exists peculiar to each night and that more accurate results can be secured by increasing the number of pairs of stars observed rather than by observing the fewer stars on different nights.

March 23.— An At Home and reception of exceptional and unique character was held at the Observatory this evening under the auspices of the Ottawa Centre of the Royal Astronomical Society of Canada. The usual pleasant social features of such functions were much enhanced by the community of interest, astronomically, among the guests who numbered over a hundred, and were further supplemented by the many interesting demonstrations and exhibits of the work of the observatory which had been arranged by the members of the staff. After being received by the wives of the officers, Mrs. Plaskett, Mrs. Stewart and Mrs. Smith, kindly assisted by Mrs. Klotz, the guests spent a couple of hours in viewing the exhibits which had been carefully arranged so that everyone was able to get a good idea of the numerous branches of work successfully carried on at the observatory. From the method of recording the disturbances set up by earthquakes to

the radial motions of the stars, from the apparatus used in obtaining and transmitting correct time to the accurate geodetic survey of the country, from the rotation of the sun to topographical surveys of international boundaries are far cries, and yet these and many other exhibits showed the wide range of the work carried on by the observatory under the able direction of Dr. W. F. King, C.M.G.

Transportation to and from the Observatory was much facilitated by the courtesy of the Ottawa Electric Railway company in supplying a ten minute service during the evening. The music which was supplied by Graziadei's Orchestra and the refreshments which were tastefully arranged and served added to the enjoyment of the evening. The committee are to be congratulated on the completeness of the arrangements.

The guests were unanimous in averring that the At Home was one of the most unique and delightful ever given in Ottawa and in expressing the hope that it might be made an annual affair. C. E.

At Peterborough

March 21.— After the formal business had been transacted Mr. T. A. S. Hay, city engineer, gave a short address on "How the Distances of the Heavenly Bodies is Measured." As there were other addresses to follow, Mr. Hay confined his remarks to illustrating, with the aid of diagrams, how the measurements in general were made and verified by surveyors and others engaged in such operations. The address was very interesting and instructive. At another opportunity Mr. Hay will complete his subject.

Dr. Marsh gave a short talk on definition of terms used in astronomy, of latitude and longitude, in their relation to terrestrial objects, and to the sky. He also added explanations of the ecliptic, horizon, zodiac, all of which were clearly and interestingly defined.

Mr. H. B. Collier, president of the Local Centre, and who is leaving town to reside in Toronto, gave a short address, regret-

ting that he would be obliged to withdraw from active participation in the affairs of the Centre, though continuing to be a member.

Rev. Dr. Winchester, of Toronto, who was present, made a few remarks, encouraging the study of astronomy and kindred sciences, as being elevating and helpful in forming character and tending to the making of better and more intelligent citizens.

At the close of the meeting the Council of the Centre adjourned to Hooper's palm room, where a supper was served in honor of the retiring president. Mr. H. O. Fiske filled the chair.

March 27.—A special meeting was held in St. Andrew's Presbyterian Church, Brighton, of which Rev. A. K. McLeod, one of our members, is pastor. The representatives from Peterborough were Mr. H. O. Fiske, Mr. T. A. S. Hay (who acted as chairman) and Rev. D. B. Marsh, who delivered an address introductory to the study of astronomy. Great interest was shown in the meeting.

April 11.—Dr. Marsh gave an account of a recent address of Professor Ritchey, of the Solar Observatory, Mt. Wilson, California, given in Toronto. The lecture was one of great interest, great advances having been made by the use of instruments already completed and still greater being promised by instruments under construction.

Mr. Seger, who is using one of the telescopes of the Local Centre, recounted his observations on the planet Jupiter and the sun.

April 18.—Mr. A. B. Ferrier, of 300 Maitland Avenue, Peterborough, was elected a member of the Society.

Dr. Marsh showed some slides of stars clusters made by Professor Ritchey, and then gave a lecture on "Jupiter."

D. B. M.

NOTES FROM THE DOMINION OBSERVATORY

ASTROPHYSICS

b PERSEI

Thirty-six plates of *b* Persei, ($\alpha = 4^h\ 10^m{\cdot}7$, $\delta = 50^\circ\ 03'$), have been taken here during the six months from October 10, 1910 to April 24, 1911. These, together with five plates taken at the Lick Observatory, give sufficient data to establish the period fairly accurately as 1·52732 days. The first four of the Lick observations,—from which the star was first branded a binary,—were distant respectively 1658, 1649, 969 and 262 periods from the first plate taken here and there was the usual trouble in being certain of the period when so short as a day and a half. However, the above period suits the measures so well that it is probably little in error. There was also some difficulty in the fact that some plates show double lines, and some others give residuals of considerable magnitude, probably due to the presence of the two spectra.

J. B. C.

σ GEMINORUM

The star σ Geminorum, ($\alpha = 7^h\ 37^m$, $\delta = +\ 29^\circ\ 07'$), has been under observation here in 1907, 1910 and the present year. Owing to its faintness — photographic magnitude 5·4 — most of the plates were made with the single-prism instrument. In general *A*-type stars have long periods, but this one is exceptional in having a fairly short period, namely, 9·60 days. The eccentricity of the orbit is small. The determination of the elements is practically complete and a paper on the orbit will be published at an early date.

W. E. H.

MAGNETIC OBSERVATIONS

In continuation of the recently inaugurated systematic magnetic survey of Canada the following stations were occupied during the season of 1910.

The 44 stations of the first list are distributed over Western Ontario, between Napanee and Windsor, and are at intervals of 25 miles.

The instruments used on this survey were a Cooke magnetometer, for declination and horizontal intensity; a Kew dip circle for inclination; and a Watt transit for azimuth and latitude. Comparison observations for standardizing the magnetic instruments were made at the Agincourt Magnetic Observatory before and after the field work.

From the above magnetic observatory records a table was prepared for the diurnal variation which was applied to the individual stations to reduce to the mean declination of the respective day.

The 48 stations of the second list are all along the main line of the Canadian Pacific Railway, and are about 25 miles apart. The observations at these were more extended. In each case were the eastern and western elongations observed, from which the mean and adopted declination was obtained. Observations for declination were taken at other times too, for the purpose of eventually preparing a table of diurnal variation for those more northerly parts. For these stations the instruments were a Tesdorpf magnetometer; Kew dip circle; and Watt transit. As in the preceding case observations were made at the Agincourt Magnetic Observatory before and after the field work.

In the last table comparison is made of observations taken at corresponding stations by the Carnegie Institution in 1906 and by the Dominion Observatory in 1910. The annual change for Ft. William is rather large. It is to be noted, however, that the stations were not identical, and furthermore, the proximity of the electric cars probably affected the declination.

With each succeeding year our knowledge of the secular variation throughout Canada will increase, as it is the intention to re-occupy stations every year.

MAGNETIC RESULTS FOR 1910

ONTARIO

OBSERVER, J. W. MENZIES.

Station	φ		λ		Date		Decl.			Dip.		Hor. Int.	Total Int.
	°	′	°	′	1910		°	′		°	′		
Napanee	44	15·9	77	00·0	Nov.	9, 11	10	36·8	W	74	25·2	·16369	·60946
Belleville	44	9·2	77	25·5	"	12-16	8	55·0	W	74	55·0	·15760	·60563
Brighton	44	2·0	77	44·0	"	19	8	42·0	W	74	48·0	·15957	·60900
Peterborough	44	18·6	78	18·5	"	5, 7	8	45·5	W	74	42·0	·16327	·61914
Newcastle	43	54·3	78	31·8	"	22	7	47·5	W	74	43·3	·16083	·61034
Kinmount	44	47·1	78	38·0	"	3, 4	8	40·6	W	75	16·9	·15488	·60960
Lindsay	44	21·0	78	44·0	Oct.	26-29	7	35·6	W	75	03·9	·15726	·61421
Pickering	43	51·3	79	4·3	Nov.	2	7	07·9	W	74	44·1	·16124	·61242
Niagara Falls	43	07·7	79	6·3	Sept.	20, 21	6	00·3	W	74	12·0	·16490	·60562
Beaverton	44	26·0	79	07·0	Oct.	25	7	31·8	W	75	3·2	·15802	·61267
Port Colborne	42	53·2	79	14·3	Sept.	17	5	47·5	W	73	58·1	·16754	·60666
Orillia	44	35·8	79	25·3	Oct.	22, 24	5	38·6	W	75	29·7	·15389	·61442
Beamsville	43	11·5	79	28·5	Sept.	22	5	51·3	W	74	31·4	·16481	·61762
Barrie	44	23·7	79	42·5	Oct.	18, 19	6	46·1	W	75	20·1	·15535	·61363
Brampton	43	40·9	79	45·5	Aug.	1, 2	5	56·5	W	74	34·7	·16293	·61270
Cayuga	42	58·0	79	51·0	Sept.	16	6	34·7	W	73	50·3	·17044	·61233
Hamilton	43	14·4	79	54·0	"	23-27	5	32·4	W	74	19·2	·16534	·61177
Penetanguishene	44	46·4	79	58·0	Oct.	20, 21	7	29·6	W	75	32·4	·15318	·61345
Orangeville	43	54·7	80	05·0	"	17	6	01·8	W	74	42·9	·16190	·61414
Guelph	43	33·0	80	15·0	Aug.	4	5	50·0	W	74	28·2	·16438	·61395
Brantford	43	08·7	80	15·5	Sept.	29	4	43·8	W	74	13·8	·16623	·61164
Simcoe	42	51·0	80	19·5	"	5, 6	4	54·2	W	74	05·8	·16805	·61329
Berlin	43	26·9	80	30·0	"	15	5	34·0	W	74	27·7	·16467	·61471
Port Rowan	42	38·0	80	27·5	Aug.	6, 8	4	39·6	W	73	49·3	·17033	·61132
Flesherton	44	14·9	80	33·5	Oct.	15	5	26·2	W	74	56·0	·15592	·60021
Woodstock	43	07·5	80	43·5	Sep.	30, Oct. 1	3	53·6	W	74	07·8	·16736	·61180
Mt. Forest	43	59·2	80	45·0	Oct.	11, 12	5	07·0	W	74	46·4	·16086	·61248
Port Burwell	42	38·9	80	49·0	Sept.	2	4	15·1	W	73	45·5	·17014	·60856
Owen Sound	44	13·3	80	55·0	Oct.	13, 14	6	01·5	W	75	13·4	·15703	·61568
Stratford	43	21·8	80	58·5	Aug.	10, 11	3	48·5	W	74	24·8	·16545	·61575
Port Stanley	42	39·9	81	13·5	"	30, 31	2	40·7	W	74	05·4	·16705	·60939
London (Hyde Park Jct.)	42	59·3	81	19·0	Oct.	3	3	34·0	W	73	59·8	·16795	·60919
Wingham	43	54·1	81	20·8	"	8	4	30·4	W	74	39·7	·16241	·61398
Lucan	43	10·7	81	24·8	Aug.	12	3	55·9	W	74	03·1	·16832	·61258
Kincardine	44	10·3	81	37·5	Oct.	10	5	25·6	W	74	38·0	·16333	·61635
Rodney	42	34·0	81	41·0	Aug.	29	3	29·9	W	73	47·3	·17138	·61373
Goderich	43	45·7	81	42·5	Oct.	5, 7	4	32·3	W	74	31·6	·16379	·61393
Forest	43	05·6	82	00·8	Aug.	13	3	41·3	W	73	57·8	·16907	·61201
Chatham	42	23·1	82	10·0	"	19, 20	2	25·9	W	73	37·5	·17252	·61194
Sarnia	42	57·7	82	22·5	"	16	3	01·3	W	73	50·5	·17045	·61248
Port Lambton	42	39·0	82	30·0	"	17, 18	2	48·7	W	73	33·0	·17333	·61209
Belle River	42	17·4	82	41·8	"	22, 23	1	49·8	W	73	21·7	·17443	·60919
Kingsville	42	02·2	82	45·8	"	26, 27	1	32·1	W	73	06·9	·17664	·60816
Windsor	42	17·9	83	15·0	"	24, 25	1	59·0	W	73	14·6	·17547	·60862

MAGNETIC RESULTS IN 1910

Along Main Line Canadian Pacific Railway

Observer, C. A. French

Station	φ	λ	Date	Decl.	Dip.	Hor. Int.	Total Int.
			1910				
Ottawa	45 23·6	75 43·0	Apr. 13	2·2 W	75 39·8	·15114	·61037
Agincourt	43 47·0	79 16·0	May 6	3·1 W	74 38·3	·16275	·61436
Chapleau	47 50·3	83 25·6	" 7, 9	4 16·4 W	77 51·7	·13219	·62866
Wayland	43 2·4	83 49·9	" 10, 11	5 8·8 W	77 58·0	·13067	·62677
Missinaibi	48 18·8	84 5·2	" 14, 16	5 48·8 W	77 49·9	·13272	·62965
Grasett	48 27·3	84 37·6	" 19, 20	3 45·1 W	78 9·6	·12878	·62765
White River	48 35·2	85 16·3	" 23, 25	3 11·9 W	78 19·4	·12768	·63087
Montizambert	48 41·3	85 38·6	" 27, 28	2 22·3 W	78 25·3	·12698	·63266
Heron Bay	48 39·3	86 17·3	" 30, 31	2 33·4 W	78 3·9	·13087	·63283
Middleton	48 47·7	86 40·3	June 4	17 48·9 E	80 22·0	·10418	·62256
Schreiber	48 48·5	87 16·6	" 7	0 31·7 W	78 26·2	·12626	·62988
Gravel	48 54·7	87 43·6	" 10	0 25·1 E	78 35·0	·12453	·62912
Nipigon	49 0·7	88 15·9	" 11, 13	1 7·0 E	78 29·6	·12653	·63429
Dorion	48 46·8	88 32·0	" 14	1 39·3 E	78 17·3	·12826	·63186
Mackenzie	48 33·0	88 58·5	" 15	2 49·3 E	78 13·0	·13021	·63816
Fort William	48 23·9	89 14·9	" 17, 18	3 16·5 E	77 49·4	·13322	·63159
Kaministikwia	48 31·5	89 35·1	" 22	0 25·3 E	80 3·5	·10746	·62243
Raith	48 49·8	89 53·6	" 23-25	3 49·8 E	78 11·0	·12954	·63258
Savanne	48 57·0	90 14·0	" 27, 28	4 28·1 E	78 12·2	·12951	·63349
Niblock	49 16·3	90 41·3	" 30, 31	4 54·5 E	78 10·8	·13018	·63553
Martin	49 15·3	91 7·9	July 2, 4	4 58·1 E	78 9·3	·13089	·63766
Ignace	49 25·4	91 40·5	" 6-8	6 10·5 E	78 30·1	·12678	·63600
Taché	49 35·0	92 10·7	" 11, 12	6 57·4 E	78 22·9	·12772	·63419
Wabigoon	49 43·6	92 36·8	" 13, 14	7 39·0 E	77 49·6	·13364	·63376
Dryden	49 47·4	92 50·1	" 16, 17	8 14·1 E	79 22·6	·11565	·62733
Eagle	49 47·7	93 11·1	" 18-20	6 34·7 E	78 10·4	·13050	·63674
Vermilion Bay	49 51·3	93 23·5	" 22	7 42·8 E	78 59·6	·12180	·63824
Hawk Lake	49 58·3	93 59·7	" 23, 24	7 28·4 E	78 26·8	·12806	·63941
Kenora	49 46·2	94 29·0	" 26, 27	10 0·4 E	77 59·4	·13122	·63062
Kalmar	49 45·7	94 58·0	" 28, 29	9 31·7 E	77 52·7	·13345	·63551
Rennie	49 51·5	95 33·3	" 29-31	10 19·7 E	77 27·7	·13779	·63471
Whitemouth	49 57·0	95 57·8	Aug. 1, 2	10 57·0 E	78 10·3	·13083	·63826
Norquay	49 59·6	96 33·9	" 4, 5	11 23·0 E	78 41·5	·12549	·63996
Winnipeg	49 51·9	97 7·9	" 8, 9	13 56·7 E	78 11·3	·13061	·63807
Marquette	50 4·1	97 43·0	" 11, 12	13 17·7 E	78 5·9	·13039	·63225
Portage la Prairie	49 58·5	98 17·9	" 15, 16	9 26·9 E	78 29·0	·12810	·64161
MacGregor	49 58·4	98 47·4	" 17, 18	13 9·6 E	77 40·4	·13502	·63246
Carberry	49 52·5	99 21·6	" 19, 20	15 44·0 E	77 39·1	·13529	·63263
Brandon	49 52·0	99 58·8	" 23-25	15 3·9 E	77 32·2	·13687	·63420
Griswold	49 46·9	100 28·7	" 26	16 4·6 E	77 15·9	·14005	·63531
Virden	49 51·3	100 55·7	" 27, 28	16 43·1 E	77 10·1	·13976	·62930
Kirkella	50 1·9	101 22·4	" 30, 31	16 13·9 E	77 17·5	·13931	·63326
Wapella	50 15·8	101 58·4	Sept. 1, 2	17 50·6 E	77 22·9	·13803	·63185
Broadview	50 22·3	102 34·7	" 3, 5	17 13·3 E	77 38·9	·13515	·63180
Wolseley	50 26·3	103 15·5	" 9, 10	18 18·1 E	77 20·7	·13850	·63219
Indian Head	50 32·2	103 39·5	" 12, 13	19 32·7 E	77 3·0	·14147	·63176
Balgonie	50 29·6	104 16·1	" 14, 15	18 57·6 E	77 3·8	·14071	·62852
Regina	50 26·9	104 36·8	" 16, 17	19 26·8 E	76 58·2	·14210	·63034
Pense	50 24·7	104 59·1	" 19	19 45·5 E	76 53·6	·14222	·62717
Moosejaw	50 23·9	105 30·9	" 20-23	19 52·9 E	77 0·6	·14096	·62709
*Agincourt	43 47·0	79 16·0	Oct. 6	5·4 W	74 39·4	·16244	·61391
Ottawa	45 23·6	75 43·0	" 20-26	13 3·2 W	75 41·1	·15096	·61053

*The values for Agincourt represent the means of the month, and were obtained from the *Journal of the Royal Astronomical Society of Canada* for May-June and for November-December, 1910.

SECULAR CHANGE

We have now for a few stations in our survey data wherefrom we can deduce secular change in declination, by comparison of the magnetic results obtained by the Carnegie Institution in 1906 and by the Dominion Observatory in 1910 at corresponding stations, as shown in the following table. From them is deduced the average annual change for the mean period of the respective observations.

Westerly declination is – ve, easterly declination + ve. In the column "Average Annual Change" for declination, a minus sign indicates that western declination is increasing, and eastern declination decreasing, while the plus sign means the reverse.

Station	Declination					Dip.			Horizontal Intensity		
	Carnegie Institution 1905	Dom. Observatory 1910		Average Annual Change	Carnegie Ins. 1906	Dom. Ob. 1910	Average Annual Change	Carnegie Ins. 1906	Dom. Ob. 1910	Average Annual Change
	° ′		°	′	° ′	° ′	′	C. G. S.	C. G. S.	γ
Ottawa	Oct. −12 44·4	Oct.	−13 03·2	−4·7	75 39·1	75 41·1	0·5	·15222	·15096	31
Chapleau	Sept. − 4 04·4	May	− 4 10·4	−3·5	77 50·6	77 51·7	0·3	·13292	·13219	20
Missinaibi	" − 5 39·1	"	− 5 48·8	−2·7	77 51·6	77 49·9	−0·5	·13373	·13272	8
White River	" − 3 00·6	"	− 3 11·9	−3·1	78 15·9	78 19·4	0·9	·12693	·12768	38
Schreiber	" − 0 22·4	June	− 0 31·7	−2·5	78 24·8	78 26·2	0·4	·12707	·12626	22
Nipigon**	" 1 17·5	"	1 07·0	−2·8	78 28·6	78 29·6	0·3	·12742	·12653	24
Fort William*	" 3 37·2	"	3 16·5	−5·5	77 48·0	77 49·4	0·4	·13414	·13322	25
Savanne	" 4 33·8	"	4 28·1	−1·5	78 09·9	78 12·2	0·6	·13038	·12951	23
Ignace	" 6 14·6	July	6 10·5	−1·1	78 27·4	78 30·1	0·7	·12791	·12678	29
Eagle	" 6 39·7	"	6 34·7	−1·3	78 07·8	78 10·4	0·7	·13135	·13050	22
Kenora	" 9 54·1	"	10 09·4	+1·6	77 58·9	77 59·4	0·1	·13176	·13122	14
Winnipeg	" 13 59·0	Aug.	13 56·7	−0·6	78 07·4	78 11·3	1·0	·13165	·13061	26
Brandon*	" 15 00·2	"	15 03·9	+0·9	77 28·7	77 32·2	0·9	·13807	·13687	31
Kirkella	" 16 02·4	"	16 13·9	+2·9	77 17·7	77 17·5	0·1	·13996	·13931	17
Brodeur.ew	" 17 05·7	Sept.	17 13·3	+1·9	77 37·5	77 38·9	0·3	·13588	·13515	18
Regina*	" 19 12·0	"	19 20·8	+3·7	76 56·8	76 58·3	0·4	·14285	·14210	10

** C. I. station about 15 feet from D. O. Station.

* C. I. station and D. O. stations not identical.

DOMINION OBSERVATORY,
OTTAWA, CANADA,
May, 1911.

OTTO KLOTZ.

NOTES FROM THE METEOROLOGICAL SERVICE

Summary Report of the Weather in Canada

February, 1911

Temperature. — In British Columbia south of the 54th parallel, the southern districts of Alberta and in south western Saskatchewan, and from the eastern counties of Ontario to and including the Maritime Provinces, the mean temperature for February was below the average, while in all other parts of Canada the normal was exceeded.

Departures from normal were pronounced. In northern British Columbia and the Yukon Territory the positive departures were from 4° to 8°, this being also the case in Manitoba and Ontario, while there were negative differences of 4° to 6° in Central British Columbia, Quebec and the Maritime Provinces. In those parts of Alberta and Saskatchewan where the normal was not reached the departures were small.

Precipitation. — The amount of precipitation recorded in Canada during February was generally below the average, and in many districts considerably so. Very locally in Southern Alberta, Southeastern Manitoba and the Rainy River District, Central Ontario, the Ottawa Valley, and in the neighborhood of Halifax the precipitation slightly exceeded the normal.

Although the the snowfall was nowhere excessive, high winds in many districts caused much drifting which seriously interfered with the operation of railroads, as well as blocking country roads, more particularly during the first two weeks.

MARCH, 1911

Temperature.— The mean temperature of March was above the average throughout the Western Provinces and the extreme Western Counties of Ontario, and below the average over the greater part of Eastern Ontario, Quebec and Maritime Provinces. The line of no difference from average was approximately between Toronto and Lake Temiskaming, and westward from this the positive departure increased to 9° in Manitoba and 13° in Southern Alberta, while eastward the negative departure increased to 4° at Montreal and 5° in Prince Edward Island.

Precipitation and Depth of Snow on Ground.— The precipitation was below normal over the greater part of the Dominion. The exceptions were the Cariboo District in British Columbia, a portion of Alberta in the vicinity of Calgary, the Georgian Bay District and Peninsula of Ontario, and extreme southern localities of Quebec where positive departures were recorded. The greatest negative departures were recorded in Manitoba and Saskatchewan where precipitation only occurred on from one to six days. At the close of the month the whole of the Province of Quebec and most of Northern Ontario had a thick covering of snow, while in other parts of the Dominion there was either no snow or only a small quantity in the woods.

R. F. S.

Temperatures for February, and March, 1911

Station	February		March	
	Highest	Lowest	Highest	Lowest
Yukon				
Dawson	44	-54	36	-46
British Columbia				
Atlin	40	-36	38	28
Agassiz	53	18	61	28
Barkerville	36	-16	44	8
Kamloops	42	14	62	12
New Westminster	49	13	59	27
Prince Rupert	52	6	46	26
Vancouver	46	26	60	28
Victoria	50	24	62	27
Western Provinces				
Battleford	38	-24	50	0
Broadview				
Calgary	44	-22	64	10
Carman				
Edmonton	52	42	60	1
Medicine Hat	42	-18	70	8
Minnedosa	31	-31	44	-16
Moose Jaw	33	-28	60	- 2
Oakbank	35	-34	50	21
Portage la Prairie	32	-32	47	-12
Prince Albert	42	-32	54	- 6
Qu'Appelle	32	-30	44	12
Regina	28	-26	45	- 9
Swift Current	32	-22	62	2
Winnipeg	36	-35	52	-10
Ontario				
Agincourt	47	1	55	0
Aurora	44	- 5	53	- 4
Bancroft	44	-24	49	-20
Barrie	41	- 6	49	- 4
Beatrice	41	13	47	12
Birnam	48	10	52	5
Bloomfield	39	1	51	3
Brantford	47	5	54	1
Bruce Mines	49	-2	50	10
Chatham	57	[illegible]	59	5
Clinton	42	[illegible]	51	- 2
Cottam	51	4	59	3
East Toronto	45	0	52	- 2
Gravenhurst	43	-17	49	-22
Guelph	44	3	53	0
Haliburton	43	19	52	-18
Hamilton	47	3	54	5
Huntsville	45	-18	56	-18
Kenora				
Kinmount	41	-21	46	-21
Kingston	40	- 7	48	1
Lakefield	58	3	54	- 5
London	50	5	53	5
Lucknow	42	- 2	50	- 7
Madoc	43	-11	49	- 5
Meaford				
Midland	50	- 7	45	- 5
North Gower				
Otoanbee	39	-20	50	- 2
Ottawa	39	-20	45	7
Owen Sound	44	- 2	55	0
Paris	45	5	54	1
Parry Sound	40	-14	54	-10
Peterboro'	44	- 9	51	- 9
Point Clark			40	3
Port Arthur	44	-24	57	-12
Port Burwell	43	7	52	6
Port Dover	48	3	48	1
Port Hope				
Port Stanley	47	9	50	5
Ronville	43	-17	46	-21
Sarnia	50	7	53	8
Southampton	43	0	50	- 4
Stonecliffe	42	-28	47	-22
Stony Creek	46	1	58	4
Stratford				
Toronto	48	5	55	1
Uxbridge	43	- 8	51	4
Wallaceburg	47	10	61	6
Welland	43	2	57	- 1
White River	42	-42	48	38
Quebec				
Brome	43	-29	49	12
Father Point	32	24	48	-12
Montreal	44	- 8	45	4
Quebec	39	-16	43	- 9
Sherbrooke	44	-25	49	-12
Maritime Provinces				
Charlottetown	40	-10	48	- 8
Chatham	42	-22	51	-14
Dalhousie	35	-28	49	-16
Fredericton	44	22	50	10
Halifax	48	- 5	46	1
Moncton	44	-19	52	3
St. John	44	6	46	2
St. Stephen	44	22	52	-12
Sussex	57	24	49	- 7
Sydney	44	-13	49	2
Yarmouth	44	1	46	1

Earthquake Records by the Milne Seismograph

TORONTO

R. F. Stupart, Director.

P.T. = Preliminary Tremors. L.W. = Large Waves. Time is Greenwich Civil Mean Time, 0 or 24 h = midnight.

No.	Date 1911	P.T Comm		L.W. Comm.		Max.		End.		Max. Amp.	Durat.		Remarks
		h	m	h	m	h	m	h	m	mm.	h	m	
987	Feb.	5	4 35·1?			4	38·1	4	54·3	0·6	0	19·2	A.T. at beginning
988	"	17	2 53·5					2	55·5	0·05	0	2·0	
989	"	17	14 40·0					14	44·4	0·05	0	4·4	
990	"	18	2 7·6	2	10·7	2	14·2	2	23·2	0·3	0	15·6	
991	"	18	2 41·6					2	43·4	0·15	0	1·8	
992	"	18	19 4·7	19	20·4	19	38·8	20	50·7	2·8	1	46·0	Itali'n earthquake
993	"	18	22 0·9					22	4·9	0·05	0	4·0	
994	"	18	22 17·0	22	19·0	22	21·1	22	38·6	0·2	0	21·6	
995	"	10	2 30·2			2	31·4	2 2	33·4) 41·4)	0·2	0	11·2?	
996	Mar.	2	19 20·2					19	25·7	0·2	0	5·5	[currents
997	"	11	3 56·6) 4 25·4)			4	34·1	4	48·6?	0·1	0	52·0	Mixed up with air A. T. previous to
998	"	19	4 41·2?			4	46·9	5	2·6	0·15	0	21·4	[beginning

Period 14·8 seconds. Period 1 mm. = 0″·64.

VICTORIA, B. C.

E. B. Reed, Superintendent.

No.	Date 1911	P.T. Comm.		L.W. Comm.		Max.		End		Max. Amp.	Durat.		Remarks
		h	m	h	m	h	m	h	m	mm.	h	m	
1011	Feb.	3	21 38·8	21	42·3	21	42·6	21	52·6?	0·3	0	13·8	
1012	"	5	Air bubble			5	0·7	5	5·0	0·05			
1013	"	12	12 55·2					13	58·4	0·05	0	3·2	
1014	"	17	2 51·3					2	52·1	0·05	0	0·8	
1015	"	17	14 41·1					14	44·9	0·05	0	3·8	
1016	"	18	2 7·0	2	12·1	2	13·9	2	31·0	0·25	0	24·0	
1017	"	18	19 5·3	19	25·3	19	31·5	2	14·3	1·3	1	59·0	Central Italy
1018	"	18	21 58·3					2	20·3	0·05	0	2·0	
1019	"	18	22 25·3	22	28·3	22	34·8	22	44·8	0·1	0	19·5	
1020	"	19	2 40·1					2	49·3	0·05	0	9·2	
1021	Mar.	2	19 24·1					19	28·4	0·05	0	44·7	
1022	"	11	4 0·3?					4	45·1	0·05	0	44·7	Gradual thickening
1023	"	15	2 25·8			2	26·9	2	32·2	0·2	0	6·4	
1024	"	19	4 54·5?					5	14·8	0·05	0	20·3	

Period 15 seconds. Period 1 mm. = 0″·76

J. V.

MAGNETIC OBSERVATIONS

During the month of February the magnetic curves show almost continuous disturbances but generally of small amplitude. On the 21st a moderate disturbance began which lasted to the end of the month; the range of declination was 1° 7'·0 and of Horizontal Force 415γ. Auroræ were also recorded during this period in all parts of Canada.

During the first three weeks of March no disturbances of magnitude were recorded and the curves were generally normal. From the 20th to the 29th the magnets were continuously moderately disturbed and auroræ of the 1st class were recorded in the western provinces and of the 2nd and 3rd class elsewhere in Canada.

Declination

Month	Mean of Month	Max.	Date	Min.	Date	Monthly Range	Amplitudes—Mean Daily: From hourly readings	Amplitudes—Mean Daily: From Means of Extremes
1911	° ′	° ′		° ′		° ′	′	′
Feb.	6 7·0	6 35·0	21	5 28·0	21	1 7·0	5·8	20·6
Mar	6 7·1	6 30·0	20	5 24·5	19	1 5 5	6·3	21·2

Bifilar

	C.G.S. units							
Feb.	·16211	·16281	28	·15865	21	·00416	·00019	·00070
Mar.	·16204	·16268	24	·16096	20	·00172	·00027	·00062

Inclination

Month	Mean
	° ′
February	74 39·2
March	74 39·2

ASTRONOMICAL NOTES

HALLEY'S COMET IN CEYLON, from local newspaper, April 21, 1910.— The morning was perfectly clear, and the Comet, with a tail 300-400 yards long was plainly visible to the naked eye in a north-easterly direction, head downwards.

April 22 :— With reference to the paragraph which appeared in yesterday's issue regarding Halley's Comet being visible at Nuwara Eliya, Mr. J. C. Lallyett telegraphs to say that the Comet's tail is 300-400 feet and not yards long as stated yesterday.

THE MOTION OF CERTAIN STARS IN SPACE.— As an extract from the *Bulletin Astronomique*, we have received a paper in which Professor Stroobant discusses the question of the sun being a member of a group of stars having a common motion through space. In the result, he finds a fairly strong indication that the sun does belong to such a system, which also comprises the stars α Cassiopeiæ, β Persei, α Persei, α Scorpionis, γ Cygni, and ϵ and α Pegasi.—*Nature*, April 20, 1911.

BABYLONIAN ASTROLOGY.—The strength of modern astrology lies in the infinite mass of details which it presents; it is impossible to do for it what the late R. A. Proctor did for the Great Pyramid delusion, *i. e.*, reduce the statements to a few algebracial formulæ, when the unreality of the mysterious relations claimed for that building became apparent at once. But through all the elaborate technicalities and multiplied calculations of modern astrology this great root assumption may still be traced. You do not know how certain events will happen,

but you can easily find out by resorting to some form of chance —the spinning of a penny, the shuffling of cards, the place of a planet. The unknown will be revealed by the unknown; the unknown event will be shown by the position of the planet, because that too is unknown before the almanac is consulted and the horoscope drawn. And irrational and insane as this assumption is, it still appears sound and indubitable to tens of thousands of persons in this "enlightened" Twentieth Century.—E. W. MAUNDER, *Journal British Astronomical Society*, No. 5,

REGARDING THE RESULTS OF OBSERVATIONS OF HALLEY'S COMET, D. Eginitis, Director Observatory, Athens, in *Astronomische Nachrichten*, No. 4468, concludes:—In another point of view, the polariscopic observations seem to confirm the hypothesis of the reflection; as is known, many observers have found that the caudal light is partially and strongly polarized. And this polarization would be very difficult to explain without this hypothesis. Besides, the photometric measures of Mr. Nordmann tend also to prove that "the light of the nucleus is almost exclusively, if not entirely, sunlight" (*C. R.* p. 1734).

But what must be the physical constitution of the comet in order that the increase of its brilliancy, observed May 21, should be so great? It is evident that the greater this difference is, the more improbable is the hypothesis of a constitution purely gaseous. The hypothesis that is thus confirmed is rather that of a mass composed of gas and containing solid corpuscles for the tail, or solid bodies of some unknown substance for the head. This result, which tallies well with the observations, agrees also with the theory of cometary origin and with the accepted ideas about the physical constitution of the mass of shooting stars. Moreover, this result conforms to the hypothesis of the production of cometary tails by the pressure exerted by the sun's rays; this theory would, in fact, be inadmissable in the case of a purely gaseous constitution of comets.

THE INFLUENCE OF PLANETS ON THE FORMATION OF SUN-SPOTS.—The following is a summary of a paper presented last month to the Royal Society, by Prof. A. Schuster, F.R.S.:—

In this investigation the relative position in heliocentric longitude of a planet, and that point of the sun's disc where a spot is first observed, is taken as starting point. Spots first noticed within 60° of the eastern limb were excluded on account of the possibility or probability that these spots were formed in the invisible hemisphere and only brought into view by the rotation. The total number of spots taken into account was about 4,250. Imagine an observer placed on the sun. He might observe within each solar rotation, imagined to be divided into 24 hours, a planet rising, reaching a maximum altitude, called "planetary noon," descending and setting.

The chief results of the investigation, dealing with the planets Mercury, Venus, and Jupiter, are as follows:—

1. More spots are formed when the planet is above the horizon than during the planetary night. The excess amounts to 4·5 per cent. in the case of Mercury, 6·4 per cent. in the case of Venus, and 1·5 per cent. in the case of Jupiter. The probability that this excess is accidental in the case of Mercury and Venus is about 1 in 7 and 1 in 17 respectively. In the case of Jupiter the difference is no more than might be expected by the theory of chance Not much importance is attached to each of these results taken separately, but if the theory of probability be applied to the combined results, an accidental coincidence of the excesses of one hemisphere over the other to the amounts indicated will not happen more than once in 1,150 cases.

2. More decided results are obtained if the formation of spots during different parts of the planetary day are investigated. If the distribution were purely accidental, twice as many spots should form during the 8 hours after the planet has risen as in the 4 hours before it sets. It is found on the contrary that during the latter interval the number of spots bears a proportion of ·344, ·349, and ·347 respectively to the whole instead of ·333, the planets always being taken in order of distance from sun. The average excess here amounts to about 5 per cent.

3. The effect of the planets when compared in detail exhibits remarkable similarities. At an observing station on the

sun, a strong minimum of spot formation is found to exist shortly before the planet rises; this is followed by a decided maximum in all three cases one hour after the rise. This is succeeded by a drop in activity, leading to a minimum, which occurs sooner with Mercury and Venus than with Jupiter, but this distinction may be accidental. The most remarkable feature in all three cases is the rapid rise from a secondary minimum, one hour after the planetary noon, to a pronounced maximum two hours later. This is followed by a drop lasting until the hour before the planets sets. The action after that and during the greater part of the planetary night is irregular, and might disappear if a larger quantity of material were available. The probability that all three planets should show their greatest activity at the same hour to the extent shown by the figures is one part in 130 million. The probability of the corresponding minimum in the planetary morning is not much less, so that taking the coincidence of both these factors into account, we may exclude the possibility of an accidental coincidence.—*Journal British Astronomical Association*, No. 6.

The Satellites of Mars.—Prof. Lowell describes observations of these satellites. Phobos generally appeared the brighter. On 1909, September 16, with full aperture, it was half a magnitude brighter than Deimos; with reduced aperture it was fainter. Prof. Lowell finds that the diameter of Phobos is 2·48 times the diameter of Deimos, and his observation suggest a difference of brilliancy in one or both of the satellites depending on its position in its orbit, and indicating that it always keeps the same face towards its primary.—*Lowell Observatory Bulletin*, No. 50.

A Kinetic Theory of Gravitation. Charles F. Brush.—(A paper read before the American Association for the Advancement of Science, 1910, December). The author asks whence comes the energy acquired by a falling body? The answer that before the fall it had potential energy of position is unsatisfactory. If a pound weight is removed from the surface

of the earth to the point between the earth and the moon where their attractions are equal, more than twenty million foot pounds of work have been expended, which are certainly not resident in the weight. The author believes that it has been absorbed by the æther. The suggestion advanced is that gravitation is due to a wave motion, the waves being either longitudinal or transverse, but of such period and wave-length that they cannot be absorbed by molecules as are waves of radiant energy. They may be compared with ocean billow, the radiant energy waves being like wind ripples. Gravitation is thus analogous to light pressure, but the wave-length being so great the waves penetrate the mass of substance, and their effect is proportional to mass and not to surface. Two bodies in space shield each other from these waves just as they give rise to shadows, and hence they are pushed towards each other. The theory is advanced with diffidence, but in the hope that it may contain some germs of truth. Attempts to find some molecular system which would resonate to these waves and so store up their energy have not yet met with success, but are being continued.—*Nature*, March 23.

Distribution in Globular Star Clusters, H. C. Plummer, *Monthly Notices*, R. A. S., March, 1911.—Among the most remarkable objects in the sky must be reckoned the globular clusters. They suggest a number of interesting problems, the most elementary and fundamental of which is concerned with the statistical arrangement of the stars they contain. Simple counts form the basis of this study, and these can be made very easily when we possess good photographs. The close aggregation of the stars, however, demands high resolving power of the telescope, and the technical difficulty in photographing these objects successfully is very considerable. Hence the structure of stellar clusters has only received serious study in recent years. The first important investigation of the subject was made by Professor E. C. Pickering about twenty years ago. He arrived at these two main conclusions:—

(1) The law of distribution is essentially the same for different clusters.

(2) The bright stars and the faint stars of a cluster obey the same law. . . . . .

More recently Dr. v. Zeipel has made an important contribution in a study of the cluster *M* 3. He has shown how the law of distribution in space may be deduced numerically from the observed law of distribution in the projection as we see it. Further he has compared the distribution so determined for the clusters *M* 13 and ω Centauri with the densities to be expected in a spherical mass of gas in isothermal equilibrium. The result is to represent the central parts of the cluster satisfactorily, while in the outer parts the cluster is less dense than this theory requires. . . . . .

It is proposed in this note to pursue the search for a physical basis on which the distribution of stars in clusters may be established. And first we examine the statistical relations between the density of the stars in space and the numbers obtained by different methods of counting. . . . . .

If we suppose that a globular cluster is the outcome of a primitive sperical nebula, it is reasonable to expect that the density of matter at different distances from the centre will be approximately preserved. It is natural, therefore, to look for guidance to possible conditions of equilibrim in a spherical mass of gas. . .

We have thus found that the evidence drawn from the Harvard material lends support to the idea that the distribution of stars in clusters resembles the distribution of density in a gravitating sphere of a particular kind of gas to which Schuster's solution applies. It would seem, at all events, that this simple form of law deserves to be borne in mind when further statistical results become available. . . . . .

The cluster *M* 3 is compared with the same law and found to be marked by a higher degree of condensation towards the centre than can be reconciled with the law. It is suggested that this can be explained by supposing that the original nebular matrix possessed a central core in isothermal equilibrium, with an outer envelope in convective equilibrium.

J. R. C.

NOTES AND QUERIES

Communications are Invited, Especially from Amateurs. The Editor will try to Secure Answers to Queries.

Audibility of the Aurora

In Volume I. (page 193) of this Journal, under the above heading, Dr. W. F. King gave an interesting account of some observations of sounds accompanying brilliant auroræ. As there are many who still have doubts regarding the reality of this phenomenon any definite evidence relating to it is very welcome. Recently the Secretary of the Society received a communication from Mrs. Consuelo Craig, wife of Mr. George Craig, of the Department of Justice, dated at Dawson, Yukon Territory, March 21, 1911, giving a clear account of auroral sounds, which I am pleased to present below : —

" About 1.30 a.m., on January 26, as Mr. Craig and I were returning home after spending an evening out, we were startled by unusual sounds, seemingly from above us. We were not *looking* for auroral displays as the temperature was about fifty below zero, (much too cold for indulging in astronomical observation), and were skurrying home with heads bent down into our fur storm-collars, and with no thought of anything except the desirability of reaching our own fireside as quickly as possible.

We were arrested by strange sounds, like the swishing and brushing together of partices of finely-broken glass. The sound came in great waves, passing slowly backwards and forwards over the auroral arc. Sometimes the wave, with its musical tinkling, would almost seem to surround us : then it would recede so far as to be almost inaudible. Then again it would come nearer, and then drop down quite near to us and then recede again up high over head. For the most part, however, the wave travelled back and forth regularly over the auroral arc, nearest to us.

Our "fifty below zero" mist enveloped the heavens and the earth, but, as far as we could see, there were no "streamers" and no "corona," merely two pretty well-defined arcs.

I have for many years taken a deep interest in auroræ, both light and dark, and have during my eleven years' residence in the Yukon seen some splendid displays; but with the exception of the present instance I have never heard anything approaching a sound coming even from the brightest of them.

I may mention that we were crossing the Park at the time we first heard the sounds, and everything was as near to absolute silence as could well be. As you, perhaps, are aware, there are no horses and rigs moving about at fifty below zero at midnight in the Yukon. Nothing noisier than the soft-footed Malemiut* dog.

I am told that a Mr. W. H. Wright, of Dawson, reported having heard the same sounds on the same morning at 3 a.m.

I must not forget to mention to you that I am an old member of your Society. I used to attend meetings during the presidencies of Mr. J. A. Paterson, Mr. Harvey, and Mr. Lumsden, and I remember that when attending them the question of whether any one had ever really heard auroral sounds or not was very much what the Scotch would describe as 'not proven.'"

[The Editor would be pleased to receive any further observations which Mrs. Craig may make.]

The Mystery of the Aurora

The nature of the aurora has long been a favorite subject for speculation, and definite evidence regarding it, such as that contained in the previous "Note," is very welcome. That it is electrical all scientists agree, and that it is distinctly similar to the electrical discharge in a vacuum tube meets with general acceptance, but further it is not very safe to go. Every year the present writer is asked if it is not due to reflection of sunlight from the arctic ice-fields!

*A tribe of Alaskan Eskimo. Ed.

Professor Birkeland, of Christiania, suggests that the auroræ are due to cathode rays given out by the sun, which stream through space and those which approach the earth converge to its poles, the phenomenon seen being due to fluorescence in the surrounding air. Experiments were made with a vacuum tube which closely resembled the various auroral phenomena.

Professor Störmer, a colleague of Professor Birkeland, by using a lens of one inch aperture and two inches focal length, has obtained at Bossekop over four hundred photographs of the aurora, which, he states, are confirmatory of the hypothesis just stated. Two of these interesting pictures are reproduced in *Knowledge* for April.

Goodacre's Map of the Moon

The Library of the Society has received a sample sheet of a new map of the moon by Walter Goodacre, F.R.A.S. The map has been compiled from telescopic and photographic observations, and its production has demanded seven laborious years. By competent judges it is declared to be the best map ever issued. It is being published, on a scale of sixty inches to the moon's diameter, in twenty-five sections, each twelve inches square. The price is very moderate, 22s. 6d. for the set.

Examination Answers

Apparent Time is that time taken by different localities as their daily time, but which varies from place to place, and for different communities.

Mean Time is the average time of a number of different localities.

Where the celestial equator cuts this line [the ecliptic] in two places we have the first aries and second of aries.

The planet saturn has the most satellites of any of the planets being ten in number, the ninth one having a peculiar reprobate movement. C. A. C.